Technol.

Electric Journal

University of Toronto Library

THE

ELECTRIC (CLUB) JOURNAL

111

VOL. I

FEBRUARY-DECEMBER

1904

122453
28/5/12

PUBLISHED BY
THE ELECTRIC CLUB
PITTSBURG, PA.

THE ELECTRIC CLUB

K. C. Randall, President. C. E. Downton, Secretary.

Is organized to provide a means for the effective co-operation among Westinghouse men in their engineering improvement and social recreation. There are now enrolled six hundred members, representing the Westinghouse Electric & Manufacturing Co., The Westinghouse Machine Co., The Westinghouse Air Brake Co., the Union Switch & Signal Co., the Nernst Lamp Co., The Westinghouse Foundries Co.; representing seventy-two colleges and technical schools, many countries, and experience of most varied scope. The Club holds weekly lectures of an engineering and general nature, and frequent meetings for the discussion of engineering subjects. The leaders in these meetings are engineers, who, during their service with a leading electric company, have had unsurpassed opportunities for keeping in touch with the foremost practice, not only of their own company, but of other companies and engineers. In this work they review, broaden and apply the theory, instruct and explain in connection with the design, the shop work and the use—points which the workman or the student would never observe. Once a month the Pittsburg Local Branch of the American Institute of Electrical Engineers meets in the hall of The Club.

The Club has been a success from the start, continually learning to adapt itself for further advantages to its members, learning by experience of one season to be more efficient the next, and growing rapidly in numbers.

THE ELECTRIC CLUB JOURNAL

Is the latest development of its educational work, and as association with others is always the best way to bring out the most in a man, to effect the greatest accomplishments from each one and from all together, so it is hoped by a broad association with all electrical men, accomplished through the general circulation of The Journal, to inspire young men to greater endeavor, to give to all electrical engineers a fuller knowledge of their craft, and to raise thereby the standard of the electrical profession.

The Electric Club Journal prints a judicious selection of what is best in the current work of The Electric Club, supplemented by other appropriate engineering material.

While primarily for the members of The Electric Club, edited from their point of view, and adapted to their requirements, The Electric Club Journal is equally suited to the needs of other young men who are looking forward to effective engineering work. In name, it is The Electric Club Journal; in fact, it is the Journal of the Young Engineer.

PUBLICATION COMMITTEE.

F. D. NEWBURY, J. H. SMITH, CHAS. F. SCOTT.

ASSOCIATE EDITORS.

B. G. LAMME, H. P. DAVIS, N. W. STORER,
J. S. PECK, P. M. LINCOLN.

ASSISTANT EDITORS.

A. M. DUDLEY, G. H. GARCELON, R. W. EATON.

The contents of THE ELECTRIC CLUB JOURNAL are copyrighted.

TABLE OF CONTENTS

Editorial items are designated (E)

Abry, Bertrand Buhre 643
Aid, first, to the injured—Dr. Ira N. Fix 286
Air brakes—See braking, electric railway 497, 571, 650
Airgap, of turbo-generators 301
Alternators, experimental testing—See testing electrical machinery, X 611
Alternator, interphase connections 684
Armatures 48, 115
Armature leads, breaking of, in small armatures 685
Armature, winding a railway motor—H. D. Robertson 214
Armature, winding a direct-current generator—Arthur Wagner 350
Apprenticeship course, making of a man by means of—Frank H. Taylor 177
Apprenticeship course, opportunities of the—W. M. McFarland. 645
Automobile voltmeter 428
Auto-transformer diagram — See diagrams, alternating-current, IV 410

Balancing rings—See armature, winding a direct-current generator 350
  See armatures 48
Babbitting of street railway motor bearings — See maintenance of electric railway equipment 375
Ballooning, some experiences in—R. Wikander 456
Bearings of street railway motors—See maintenance of electric railway equipment 375
Braking, electric railway—E. H. Dewson
  Part I.—Straight air brake .. 497
  Part II. — Automatic air brakes (S. J. Fuller) 571
  Part III.—Details of straight air brakes 650
Braking, electric railway (E) ... 560
Brake load for motor testing—See testing electrical machinery, VII 419
Brake, water—See turbines, commercial testing of steam 387
Brush losses—See testing electrical machinery, V 289
Bucking of railway motors 181

Cables, installation of electric—H. W. Buck 123
Carnegie gift to engineering (E)—W. M. McFarland 184
Central station development—W. C. L. Eglin 299
Commutators 50, 113
Commutators, construction of large 303
Commutators, repairing pitted ... 685
Compensating winding of alternators—See testing electrical machinery, X 611
Compounding of motors — See testing electrical machinery, VI 360
Congress, international electrical (E)—C. F. Scott 559
Control of single-phase railway motors 514
Copper castings — See foundry practice with copper and its alloys 108
Current measurement in three-phase system with two transformers 247
Curves of induction motors 431, 503, 597

Dampers, copper, in alternating-current machines 368
Diagrams, alternating current—V. Karapetoff
  Part I. — Elementary examples 159
  Part II.—Parallel and series circuits 205
  Part III.—Transformers 279
  Part IV.—Transformers 410
  Part V.—Equivalent current. 471
  Part VI.—Generators 532
  Part VII.—Induction motors. 606
  Part VIII. — Heyland diagram 658
Dielectric strength tests for oils—See transformer oil 227
Drilling small square or hexagonal holes 489
Drive, direct-current systems of electric—W. A. Dick 251
Ducts—See cables, installation of electric 123

Eddy current losses—See steel, testing of sheet 333
Education, technical (E) 371
Education, business side of technical—A. C. Humphreys 342
Electric club—H. W. Peck 17
Electric club, an apprentice's impression of (E)—S. S. J. Morgan 625
Electric Club Journal (E) 51
Elevator, electric—H. D. James .. 187
Engineer, the up-to-date 492
Engineer, the young, and his opportunities—C. F. Scott 198
Equalizer rings, action of 48
Ewing hysteresis meter — See steel, testing of sheet 333

Field coils, indestructible, for railway motors 486
Field-form measurement — See testing of electrical machinery, VIII 475
Flux distribution in three-phase transformer — See transformation, three-phase 401
Foundations of generators 181
Foundry practice with copper and its alloys—W. J. Reardon 108
Frames, structural steel, alternator 488
Frenyear, Mr., and man power (E)—C. F. Scott 118
Frenyear, Thomas Cyprian—W. M. McFarland 23

Gas engines, testing of—E. E. Arnold 522

Gas power plants—A. M. Gow... 65
Gauging, of materials—C. C. Tyler ... 310

Heyland diagram—See diagrams, alternating current, VIII... 658
Hubs of large rotating fields... 248
Hunting of rotary converters—F. D. Newbury ... 275
Hysteresis in sheet steel, measurement of—See steel, testing of sheet ... 333

Impedance, influence of, in telephone circuits—See telephone, modern ... 317
Induction motor—See diagrams, alternating current, VII... 606
Induction motors, applications to elevator work—See elevator, electric ... 187
Induction motor, polyphase — B. G. Lamme
  Part I.—Construction... 431
  Part II. — Variable speed motors ... 503
  Part III.—Methods of speed variation ... 597
Induction regulators ... 579
Induction regulator for single-phase motors — See Westinghouse single-phase railway system ... 133
Inductive drop in alternators—See diagrams, alternating current, VI... 532
Instruments, measuring, use of. 32
Insulation resistance measurement — See testing electrical machinery, IX... 542
Insulation tests for transformers ... 182
Iron-loss test for series motor—See testing electrical machinery, III... 169

Kapp's diagram, for measuring inductive resistance — See diagrams, alternating current, IV... 410

Lamb and Walker, permeability meter—See steel, testing of sheet ... 333
Line transmission, crossing railroad right of way—P. M. Lincoln ... 448
Loading back method, for testing regulation—See testing electrical machinery, IV., V... 410, 471
Losses, correction for, in choke coils—See diagrams, alternating current, II... 205
Losses, in sheet steel—See steel, testing of sheet... 333
Losses, iron and copper, in transformers (E)—J. S. Peck... 308
Lubrication of street railway motors—See maintenance of electric railway equipment... 375

Maintenance of electric railway equipment—J. E. Webster... 375
Manhole construction—See cables, installation of electric... 123
Man-power—T. C. Frenyear... 75
Man's work ... 687
Meter, power-factor... 555
Message to Garcia (E)—L. A. Osborne ... 249
Microscopic views, exhibition of. 239
Motors, efficiency tests of—See testing electrical machinery, VII... 419
Motors, regulation tests of—See testing electrical machinery, VI., VIII... 360, 475
Motor, polyphase induction... 431, 503, 597
Motor, polyphase induction (E). 491
Multiple unit system—See traffic problems of the day... 530

Oil, for transformers... 182
Oil, transformer—C. E. Skinner. 227
Opportunity of the engineer (E) H. G. Prout ... 309

Peck, John Sedgwick... 587
Permeability tests — See steel, testing of sheet... 333
Pitting of commutators... 685
Point of view (E)—C. F. Scott.. 626
Point of view—Walter C. Kerr.. 563
Polarity tests—See testing electrical machinery, IX... 542
Polyphase system, Tesla motor and the (E)... 558
Power-factor—See Westinghouse single-phase railway system.. 133
Power-factor meters... 555
Power-factor meters and their application—Paul McGahan... 462
Power-factor meter connections. 368
Power-factor, effect of, on regulation—See diagrams application of alternating current, IV. 410
Power-factor meter, test of... 554
Power-factor of induction motors—See induction motor, the polyphase ... 431, 503, 597

Railway equipment, maintenance of ... 375
Railway motor testing—See testing electrical machinery, IX.. 542
Railway motor, single-phase—C. R. Dooley ... 514
Railway, single-phase — C. F. Scott ... 5
Railway system, single-phase... 133
Regulation—See rotary converters, voltage regulation of... 55
Regulation of alternators — See diagrams, applications of alternating current, VI. Testing electrical machinery, X... 532, 611
Regulation test of alternators—See testing electrical machinery, XI... 671
Regulation of generators — See testing electrical machinery, IV ... 240
Regulation of motors—See testing electrical machinery, VI.. 360
Regulators, polyphase induction—G. H. Garcelon ... 579
Regulation, speed, of induction motors—See induction motor, the polyphase... 431, 503, 597
Regulation tests for direct-current generators — See testing electrical machinery, V... 289
Repeating coil system—See telephone, the modern... 317
Resistance device, variable... 247
Rheostats, synchronizing ... 302
Road engineer (E)—R. L. Wilson 627
Rotary converters, the hunting of ... 275

Rotary converters, voltage regulation of—P. M. Lincoln...... 55

Schmid, Albert—H. C. Ebert..... 408
Series motor, alternating current —C. F. Scott................. 5
Series motor, alternating-current —F. D. Newbury............ 10
Series motor, single-phase....... 514
Series transformer............. 451
Shops—the new east of the W. E. & M. Co.—C. C. Tyler........ 37
Short circuits 48, 116
Shunts, inductive—See diagrams, alternating-current, II........ 205
Single-phase railway motor..... 514
Slack adjusters — See braking, electric railway, III........... 650
Slip indicator—C. R. Dooley.... 590
Speed control of induction motors —See induction motor, the polyphase, II..................... 503
Speed indicator................. 181
Speed variation of induction motors—See induction motor, the polyphase, III............. 597
Starting induction motors....... 684
Steam turbines—F. Hodgkinson. 84
Steel, testing of sheet—C. E. Skinner 333
Switchboard design, modern practice in—H. W. Peck.......... 631
Switchboard, evolution of the (E) —C. I. Young................ 686
Switchboards, telephone — See telephone, the modern........ 317
Synchronizing of alternating-current machines 670
Synchronizing rheostats 302
Synchroscope—See synchronizing of alternating-current machines 679

Tandem operation of induction motors—See induction motor, the polyphase, III.......... 597
Telephone, the modern — S. P. Grace 317
Temperature rise of motors—See testing electrical machinery, VIII 475
Tesla motor and the polyphase system (E)—C. F. Scott...... 558

Testing, electrical machinery—R. E. Workman
  Part I.—Introduction........ 27
  Part II.—Experimental, direct-current 95
  Part III.—Series motors.... 169
  Part IV.—Regulation of generators 240
  Part V.—Regulation tests... 289
  Part VI.—Motors 360
  Part VII.—Brake test....... 419
  Part VIII.—Speed curves.... 475
  Part IX.—Commercial tests. 542
  Part X.—A. C. generators... 611
  Part XI.—Regulation of alternators 671
Testing (E)—N. W. Storer..... 119
Testing, shop, of gas engines—E. E. Arnold................ 522
Throw, variation of—See armature, winding a direct-current generator 350
Traffic problems of the day—Calvert Townley 530
Transformer connections — diagrams 490
Transformer diagram—See diagrams, alternating-current, IV. 410
Transformers, drying out—J. S. Peck 61
Transformers, drying out (E)—J. S. Peck 52
Transformer operation, real economy in—C. Fortescue......... 264
Transformer, series, operation of the—E. L. Wilder............. 451
Transformers, the Vector diagrams of—See diagrams, alternating-current, III............ 279
Transformation, three-phase — J. S. Peck 401
Triple valve, in air braking—See braking, electric railway, II.. 571
Turbines, commercial testing of steam—A. G. Christie......... 387
Turbo-generators 301, 47
Turbo-generator field construction 622
Turbo-generator, test of a 5500 kw.—F. P. Woodbury......... 225

Unge's design for a balloon—See ballooning 456

Voltmeter, automobile.......... 428
Voltmeter, induction type, corrections for changes of temperature 555
Voltmeter, type F, alternating-current, series resistance for.. 427

Waterglass 50
Wattmeters 35
Westinghouse, George—F. H. Taylor 1
Westinghouse single-phase railway system — Clarence Renshaw 133
Winding—See armature, winding a direct-curent generator...... 350
Winding a railway motor armature 214
Windings, induction motor, test for —G. H. Garcelon......... 148
Winding, points in transformer coil 306
Wireless telegraphy, the status of—S. M. Kintner............ 270

Young man entering the works (E)—C. F. Scott............. 429

INDEX OF AUTHORS

- E. E. ARNOLD.... 522
  - Shop Testing of Gas Engines
- H. W. BUCK.... 123
  - The Installation of Electric Cables
- A. G. CHRISTIE.... 387
  - Commercial Testing of Steam Turbines
- E. H. DEWSON.... 197, 650
  - Electric Railway Braking
- W. A. DICK.... 251
  - Direct-Current Systems of Electric Drive
- C. R. DOOLEY....
  - The Single-Phase Railway Motor.... 514
  - A Slip Indicator.... 590
- H. C. EBERT.... 408
  - Albert Schmid
- W. C. LEGLIN.... 299
  - A Note on Central Station Development
- IRA N. FIX, M. D.... 286
  - First Aid to the Injured
- C. FORTESCUE.... 264
  - Real Economy in Transformer Operation
- T. C. FRENYEAR.... 75
  - Man Power
- S. J. FULLER.... 571
  - Electric Railway Braking
- G. H. GARCELON....
  - The Polyphase Induction Regulator.... 579
  - A Test for Induction Motor Windings.... 148
- A. M. GOW.... 65
  - Gas Power Plants
- S. P. GRACE.... 317
  - The Modern Telephone
- F. HODGKINSON.... 84
  - Steam Turbines
- A. C. HUMPHREYS.... 342
  - The Business Side of Engineering
- H. D. JAMES.... 187
  - The Electric Elevator
- V. KARAPETOFF....
  - Applications of Alternating-Current Diagrams.... 159, 205, 279, 410, 471, 532, 606, 658
- WALTER C. KERR.... 563
  - The Point of View
- S. M. KINTNER.... 270
  - The Status of Wireless Telegraphy
- B. G. LAMME.... 431, 503, 597
  - The Polyphase Induction Motor
- P. M. LINCOLN....
  - Crossing a Railroad Right of Way by a Transmission Line 418
  - The Voltage Regulation of Rotary Converters.... 55
- W. M. McFARLAND....
  - Carnegie Gift to Engineering (E).... 184
  - Thomas Cyprian Frenyear.... 23
  - Opportunities of the Apprenticeship Course.... 645
- P. MacGAHAN.... 462
  - Power-Factor Meters and Their Application
- F. D. NEWBURY....
  - The Alternating-Current Series Motor.... 10
  - The Hunting of Rotary Converters.... 275
- L. A. OSBORNE.... 249
  - A Message to Garcia (E)
- J. S. PECK....
  - Three-Phase Transformer.... 401
  - Drying Out Transformers (E).... 52
  - Methods of Drying Out High-Tension Transformers.... 61
  - Iron and Copper Losses of Transformers (E).... 308
- H. W. PECK....
  - The Electric Club.... 17
  - Modern Practice in Switchboard Design.... 631
- H. G. PROUT.... 309
  - The Opportunity of the Engineer (E)
- W. J. REARDON.... 108
  - Foundry Practice with Copper and its Alloys
- C. RENSHAW.... 133
  - The Westinghouse Single-Phase Railway System
- H. D. ROBERTSON.... 214
  - Winding a Railway Motor Armature
- C. E. SKINNER....
  - Transformer Oil.... 227
  - Testing of Sheet Steel.... 333
- N. W. STORER.... 119
  - Factory Testing (E)
- C. F. SCOTT....
  - Single-Phase Series Motor in its Relation to Existing Railway Systems.... 5
  - Mr. Frenyear and Man Power (E).... 118
  - The Young Engineer and His Opportunities.... 198
  - The Tesla Motor and the Polyphase System (E).... 558
  - The International Electrical Congress (E).... 559
  - The Point of View (E).... 626
- F. H. TAYLOR....
  - George Westinghouse.... 1
  - The Making of a Man by Means of the Apprenticeship Course 177
- CALVERT TOWNLEY.... 530
  - Some Traffic Problems of the Day
- C. C. TYLER....
  - The New East Shop of the Westinghouse Electric & Manufacturing Company.... 37
  - Gauging of Materials (E).... 310
- A. WAGNER.... 350
  - Winding a Direct-Curent Generator Armature
- J. E. WEBSTER.... 375
  - Maintenance of Electric Railway Equipment
- R. WIKANDER.... 456
  - Some Experiences in Ballooning
- E. L. WILDER.... 451
  - Operation of the Series Transformer
- R. L. WILSON.... 627
  - The Road Engineer (E)
- F. P. WOODBURY.... 225
  - A Test of a 5500 kw. Turbo-Generator
- R. E. WORKMAN....
  - Factory Testing of Electrical Machinery ..27, 95, 169, 240, 289, 360, 419, 475, 542, 611, 671
- C. I. YOUNG.... 686
  - The Evolution of the Switchboard (E)

Geo. Westinghouse
Dec 16th 1903

THE
ELECTRIC CLUB JOURNAL

VOL. I. FEBRUARY, 1904. No. 1.

GEORGE WESTINGHOUSE

Response to a Toast at the Dinner in Connection with the Annual Meeting of the District Managers of the Westinghouse Electric and Manufacturing Company at the Duquesne Club, Pittsburg, December 3, 1903

By Frank H. Taylor, Vice-President

GEORGE WESTINGHOUSE:

Mechanic;	Friend of Labor;
Inventor;	Tireless Organizer;
Financier;	Founder of Enduring Industries.

What all the world knows needs only to be mentioned to you who are his associates in business:

The revolution in railroading wrought by the developed air brake;

The foresight that recognized the importance of the discovery of natural gas in the Pittsburg district and controlled its development;

The resourcefulness and ingenuity which won the great victory at the World's Fair in Chicago;

The courage that triumphed over the difficulties of a financial crisis;

The power that has led the unparalleled increase in the Westinghouse industries which, started but a few years ago, are now appalling in their size and extent;

The executive ability that has been the controlling factor in these interests, so numerous that no one here in an hour's time could write out a complete list of them.

These interests have grown so large and the number of responsible officers has become so great that Mr. Westinghouse is not as intimately known to you as I should desire, and as I am sure he himself would desire, if it were possible.

Some of the peculiarities which have aided him to acquire his present position may be illustrated. For example, it is unusual for an inventive genius to be so perfectly open-minded to the inventions of others. I sometimes think he is as happy over the discoveries of other minds as though they were his own. He has found a means for the development of new inventions all his life. Great intellects have worked for him, been encouraged and protected by him. I name at random: Shallenberger, Tesla, Scott, Parsons, Nernst, Ruud, Cooper Hewitt, Thomas, Davis, Bremer, Lamme, Wurts, Lange.

His mind is constantly reaching out into the future, and after one has been much with him it becomes practically impossible to live altogether in the present, because there is brought to view at every turn possibilities of new things yet undeveloped which are to serve future generations at a time when the world has advanced far beyond its present stage. The imagination is constantly stimulated and interest kept alive by the new principle that is struggling on towards definite shape.

There is always present the evidence of good will toward every one; a quick appreciation of the good points of other people. In the course of his life he has been forsaken by friends who lacked courage to follow him, and in its main crisis he was greatly hampered by heart-breaking incidents of this kind. Yet no one has ever heard him say an unkind word of these men. His foresight is phenomenal. The industries in this country have grown up even faster than seemed wise to a great many who were associated with him. They did not see the value of what he was doing as clearly as he saw it, and time alone has justified the thoroughness with which plans have been laid, buildings designed and executed. Energy and expense have not been spared upon any of his works. They have been developed in such a way that they can be extended forever.

No sooner had provision been made for this country than many of his closest friends were startled by a move upon Europe and the markets of the world. Some men have charged this move to a mere ambition to plant his name in Europe. They wondered that he should tax his resources and take upon himself the tremendous strain which has finally resulted in the great organizations and plants in England, France, Russia and Germany.

The associates who questioned his wisdom did not have his foresight and did not see that these things were necessary for the protection of the initial developments in the United States. I give no importance to my own judgment in this matter, but Mr. Westinghouse knew that the foundations here would have been insecure had not the foreign field been entered during his period of maximum activity. We shall live to see all the effort justified, and the Westinghouse interests the world over fitting together and helping one another.

After all, what is the ultimate aim of it? Men work for wealth, for social position, for the esteem of professional associates, for the applause of the world. These things may be nominated ambition and of that all men must plead guilty.

In the case of Mr. Westinghouse the aim is not immediate wealth. He has done his work too thoroughly to have that as his goal. From my closer observation of him I should determine that he meant to leave a monument upon the earth that shall be strong enough to stand alone without consolidation with other interests, and that shall bear his name for a hundred years. Napoleon's words to his brother when he was made ruler of Spain were: "My one word of advice to you—be master," and I anticipate that the Westinghouse interests will be master of anything they associate with during the next century. By that time the appreciation of what Mr. Westinghouse has done for the world will be clearer and more just than it is to-day.

Great men cannot be compared one with another. They are moulded by circumstances and no two are alike any more than two great trees are alike, yet no man is great who lacks certain essential qualities: First, he must at all times be just, and in the case before us this quality has prevailed. A great nature shows itself by being kind and considerate. The underlying sweetness of his spirit is illustrated by the watchword that he uses among all his interests—a constant repetition of a plea for harmonious action. Other virtues are shown by the cleanness of his life. You who have, at times, worked for other kinds of men must know the power that comes to those who work for a clean man, and one who demands soundness of thought and expression. He is never satisfied with surface appearances, but seems to look right through to the heart. His mind is so quick that he sees the essential point in a complicated situation even before the story can be fully told to him. Once determined upon his course, he is not to be laughed out of it, frightened out of it, nor bought off.

The boundless hospitality of his home has been often mentioned, but when one has had the opportunity repeatedly of seeing him there, he is impressed with the uniform cheerfulness of the man and of his sustained interest in every detail of household life. I saw somewhere a letter from a wife written upon the birthday of her middle-aged husband. In the letter this sentence appeared: "To me, you will always be my young lover." This one sentence defines Mr. Westinghouse in his home.

To one associated with him in business, it has often seemed that to be loved of the man is an aim worthy of a life of devotion to his interests.

I have referred to the fact that all men have their ambitions. Every one here is anxious for a broader field, and I am sure will attain to it. Yet every one of us has arrived at an age when we can make a fairly good estimate of our probable attainments. This is our annual dinner and it is a good time to take account of stock. My judgment is that there is in our organization an opportunity for every man to be satisfied. For myself, first of all, I want a conscience void of offense. Next, I want to leave some record in the world for my family. I should like to be remembered as one who has accomplished something. I, too, want to leave a monument. My ambition is not for popularity nor for fortune. I am satisfied if I leave my children the inheritance that their father had been able to catch something of the spirit of a great leader, and that he had been somehow useful in perfecting that leader's work and in developing his plans. For me it shall be enough that I served under George Westinghouse; that I was accounted one of his efficient lieutenants.

THE SINGLE-PHASE SERIES MOTOR IN ITS RELATION TO EXISTING RAILWAY SYSTEMS

By Charles F. Scott, Chief Electrician

In 1887 a catalogue was issued, entitled, "The Van Depoele System of Electric Railways," which gave a list of Van Depoele roads, six in all, operating a total of fourteen and three-quarters miles, and adds, "As the matter now stands we have more miles of electric railway now in successful operation than all the other electric railways in the world combined." In 1890, three years later, the mileage of single track electric railways in the United States had increased to 1,262 and in 1902 it reached 21,914. In this development the introduction of the rotary converter has been one of the most important factors, as it gave a new impetus and a new scope to electric railway working.

In the present railway system, however, the rotary converter, requiring the synchronous operation of apparatus in widely distributed sub-stations, is the weakest link in the whole system. It is costly to install, it is expensive to operate on account of loss in power and the attendance necessary, and it is the element which is most likely to interfere either directly or indirectly with continuous operation of service.

The new system employing the single-phase series motor, by leaving out the rotary converter sub-station, eliminates the weakest element in the present system. A careful consideration of the single-phase system shows that it does not involve these elements in the distributing system and in the control, which are the weakest features and the elements which limit the extension of the present system. The single-phase railway system therefore has in it the elements for a development and an extension of railway work which may far surpass even the impetus given by the rotary converter.

It is furthermore most remarkable that the new apparatus is not revolutionary in discarding the best elements of the old system, but it retains them, and not only that, but the apparatus corresponds in some features so closely with apparatus in the existing systems that it may frequently be adapted to them in ways which would be utterly impossible, for example, if the new system involved polyphase currents and induction motors.

A new railway motor must be considered not only in respect to its own characteristics and intrinsic merits, but also in connection with the general system of which it forms a part. Nor can a new railway system be considered wholly upon its own merits unless it is to be installed in a place where it has no relation to any existing electric railway. The relation of the series alternating-current motor to existing railway systems is therefore a question of first importance in connection with the introduction of the new motor, except in those cases where the new road has no connection with an existing system. The element in the present electric railway which has remained unchanged since the earliest railways and is now universal is the use of 500-volt direct current. The generators have changed from belt-driven to direct-driven, from direct current to alternating current; the transmission system has changed from heavy feeders to alternating-current transmission with rotary converter sub-stations; on the car the series motor is still the only motor, but motors have increased greatly in size and have improved in design and in reliability, and the multiple unit system of control has been introduced for larger equipments. The 500-volt trolley, however, has remained standard through the changes in the other parts of the railway system. The modern railway power-house which supplies current for operating railways through rotary converters produces alternating current at 25 cycles. The two important elements in the present system which require attention in connection with the single-phase motor are the ability of the motor to operate normally on 25 cycles and temporarily on 500 volts direct current.

The paper by Mr. B. G. Lamme, the designer of the new motor, read before the American Institute of Electrical Engineers, September, 1902, presents the alternating-current railway system *per se*. So complete was the paper that it contains practically all of the points which have been brought out in the technical press in the past year relative to single-phase railway operation.

Mr. Lamme has continued his work of developing the motor and the results of this work are of very great commercial importance in two respects.

First—Large as well as small motors may be operated successfully on 25 cycles, or 3000 alterations.

Second—Under certain conditions the motors may be operated on ordinary direct-current railway circuits.

TWENTY-FIVE CYCLES—A frequency of 16⅔ cycles (2000 alterations) was employed for the first single-phase motors. The difficulties inherent in the design of a commutating motor increase as the frequency increases. The experience gained in the construction and tests of a number of motors has led to the design of motors for 25 cycles equal in performance to that of the early motors at the lower frequency. The adoption of 25 cycles, however, makes the present alternators available for the operation of the alternating current motor, and in fact they may be used for supplying alternating current to the cars equipped with the new motor and for supplying direct current through rotary converters to the old cars. The several circuits of a polyphase alternator may supply current to different sections of a system, each of which operates single-phase motors.

An existing railway company may equip one division of its service or it may equip a new extension with the alternating-current motor and then operate both kinds of service without the necessity of having two kinds of generators. At a later time, therefore, it may be practicable to change over the whole system to alternating current employing the same power house, but discarding the rotary converter sub-stations.

FIVE HUNDRED-VOLT DIRECT-CURRENT CIRCUITS—One of the unique features of the alternating-current motor which is now being considered is its conformity to the standard type of direct-current motor. Various forms of polyphase motors and other types of single-phase motors have been considered and to some extent used in railway work. The present alternating-current motor is also a first-class direct-current motor, which not only insures that it will give the same characteristics in service which have made the series motor the only acceptable motor in direct-current work, but it also secures a type which can be operated indifferently upon alternating current or on direct current. This characteristic will be of little or no consequence on those roads, particularly new installations, where there is no direct current. There are, however, many cases where the route of a proposed railway includes greater or less lengths of track which are supplied with direct current, making it necessary or at least desirable to operate temporarily from a direct-current trolley. If the length of track which is used in common be short it may be best to install two separate trolley wires and thus keep the two systems separate. This is desirable, but is often impracticable.

Single-phase series motors are normally wound for 250 volts, so that two of the motors connected in series are suitable for operation on a 500-volt direct-current circuit. Operation by direct current makes it necessary to employ a rheostatic form of control similar to that ordinarily used with direct-current motors. It further makes it necessary to have four motors (two pairs of two in series) in order to secure the series-parallel control. In other words, two single-phase motors connected in series take the place of one direct-current motor. A four-motor equipment may therefore be operated with the ordinary type of series-parallel control. A two-motor equipment, if operated upon direct current, would make it necessary that the whole control be by means of a rheostat in the same way that a single direct-current motor would be operated. An equipment of single-phase motors with rheostatic control may be operated either upon a 500-volt direct-current circuit, or upon a 500-volt alternating-current circuit, or upon a high voltage trolley circuit of say 1000 to 3000 volts, the voltage being reduced by a transformer on the car. A given car therefore may start in a city which has a 500-volt system, running along with local cars from the same direct-current trolley; it may then go across country with alternating current at high voltage; it may then go through a village taking alternating current at 500 volts and then take high voltage again, as may be convenient.

This arrangement of control by which the car may be operated either from alternating or direct current will in general prevent the use of variable voltage control. The voltage control, in which rheostats are eliminated and the voltage appropriate for the motor is secured either from suitable loops brought out from the transformer or by means of the induction controller, is the efficient and obviously desirable one to use with the alternating-current motor. The advantage in the voltage control is greatest in those cases where stops are frequent or where the motor is run at a low speed during a considerable proportion of the time, as it is in these cases that the rheostat is in service a considerable part of the time and the rheostatic loss is large. The loss in the rheostat of an ordinary suburban car will be relatively small if the stops are infrequent. In some cases, however, in which the stops are very frequent loss in the rheostat may be as much as 15 or 20 per cent of the total power delivered to the car. It is theoretically possible to install both the rheostatic control and the voltage control on the same car, but in general this is not feasible on account of the weight, cost and complication of the double system of control.

The adaptation of the single-phase motor for operating on direct current is advantageous as above indicated for enabling interurban cars to operate on direct current in cities and on alternating current across country. It also opens another possibility. Existing railways which may desire to operate extensions of their present systems by single-phase motors or which may find it advantageous to change from their present rotary converter system to the single-phase system in the future, may make provision for so doing by purchasing alternating-current motors for operation on their present direct-current systems, thereby providing equipments which will operate upon an alternating-current system in the future. A study of the savings to be secured in sub-stations by the elimination of rotary converters with their attendants; by the reduced cost of feeder circuits, through the use of a higher trolley voltage, or the placing of sub-stations closer together; also by the saving in power through the higher efficiency of the system resulting from the elimination of losses in rotary converters and usually a less loss in circuits, presents sufficient reason why those who are about to purchase motors for their existing systems should give careful consideration to the desirability of purchasing the alternating-current motor for use on the existing direct-current circuits, as these motors are suitable for alternating current as well as direct current, and their installation provides the way for a ready change of system in the future.

THE ALTERNATING-CURRENT SERIES MOTOR

AN EXPLANATION OF ITS OPERATION

By F. D. Newbury

A Paper Presented Before the Testing Section Dec. 11, 1903

IT IS a matter of common experience that in a direct-current series motor, if the direction of current in both armature and field be changed, the armature will continue to revolve in the same direction. Then, with alternating current in the motor, and with the armature and field in series, the direction of rotation will not change with the reversals of the alternating current, and the armature will revolve just as it does with direct current.

So far as the production of mechanical energy is concerned, the action of the motor is the same whether direct or alternating current is used. The alternating current, as such, is not essential to the operation of the new motor; on the contrary, the problem has been to develop a motor that would operate in spite of certain difficulties inherent in the alternating current, so that it would have the proper speed-characteristics for railway work and, at the same time, enable the simple voltage-transformation, possible with alternating currents, to be used in other parts of the railway system. The direct-current series motor may be considered a special case of the more general alternating-current motor, for while the alternating-current motor makes an equally successful direct-current motor, the reverse is not true. From the similarity of the two motors it follows that changes in voltage, load, and so on have corresponding effects on speed and torque in the alternating-current motor as similar changes in the direct-current motor. The practical operation of the two motors is also the same. The alternating-current motor is started by lowering the voltage, either by resistance, as in the direct-current motor, or, more economically, by some form of transformer. The motor is reversed by interchanging either the field or armature connections, as in the ordinary railway motor. On account of its self-induction the alternating-current motor will stand rougher usage than the direct-current motor. For example, a 100-hp motor has frequently been started by full voltage and has been reversed, when running under full load and voltage, by simply throwing over a double-throw switch.

While, in general, the alternating-current series motor works on the same principles as the corresponding direct-current motor, several things happen inside of the former, by reason of the varying magnetic field produced by the alternating current, that are not found in the direct-current motor. A more detailed explanation of the action of the alternating-current motor may, therefore, be of interest. The phenomena characteristic of the alternating-current motor are:

(1.) An e.m.f. generated in the armature winding by the alternating magnetic field, in addition to the e.m.f. generated by the rotation of the armature.

(2.) A local current circulating in the armature coils short-circuited by the brushes, due to the e.m.f. in (1.)

(3.) An iron-loss occurring in the entire magnetic circuit, due to the alternating magnetic field.

(4.) An active e.m.f. existing between the turns of the field coils—what may be called the counter e.m.f. of the field coils.

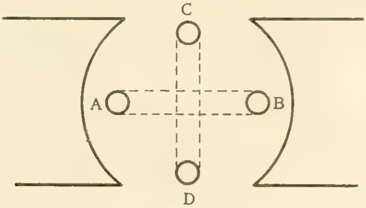


Fig. 1

(1.) THE ELECTRICALLY-GENERATED E.M.F.—With an alternating field there are two distinct e.m.f.'s generated in the armature coil; the first by the movement of the coil through the field, with a maximum value when the coil is in the position A B (Fig. 1), and a zero value in the position C D; and the second by the alternating magnetism, with the maximum value occurring when the coil is in the position C D and a zero value in the position A B. The first, or mechanically-generated e.m.f., is proportional to the speed; the second, or electrically-generated e.m.f., is proportional to the current frequency. While these two e.m.f.'s exist in the armature winding, only one—the mechanically-generated e.m.f.—appears at the terminals of the motor. The reason for this is shown by Fig. 2. In this sketch the directions of the e.m.f.'s in each part of the winding, at one instant, are shown by the arrows, the full arrows representing the mechanically-generated e m.f., and the dotted arrows the electrically-generated e.m.f. On the two sides of the line C D the mechanically-generated e.m.f. is in opposite directions, and on the two sides of the line A B the electrically-generated e.m.f. is in opposite directions. It is evident from Fig. 2 that so far as the outside circuit is concerned the electrically-generated e.m.f. neutralizes itself, and plays no part in determining the current taken by the motor. This is only true when the brushes are on the neutral points. The electrically-generated e.m.f. is of only theoretical interest, except for its effect on the armature coil short-circuited by the brush, as explained in the following paragraph.

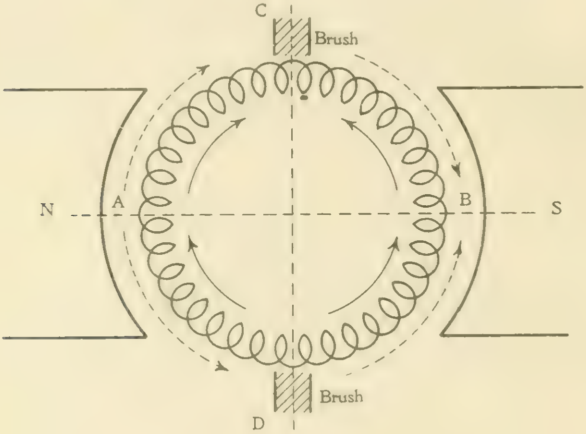


Fig. 2

(2.) The Local Armature Current—At each brush there is a local circuit in which the electrically-generated e.m.f. is not neutralized. A current results, which, if not prevented, affects commutation and increases the motor-loss. Fig. 3 shows this local circuit made up of an armature coil and the brush. It is seen that when the coil is short-circuited by the brush it is in the position of maximum value of the electrically-generated e.m.f., corresponding with the position C D (Fig. 1). This local circuit may be compared with the short-circuited secondary of a transformer, of which the field coil is the primary. The loss occasioned by the local current appears as a part of the energy component of the field voltage, the action being the same as in a transformer.

(3.) THE ALTERNATING-CURRENT IRON-LOSS—The total iron-loss occurring in the motor may be divided in two parts that occurring in the armature and pole-faces, due to the rotation of the armature, and that occurring in the entire magnetic circuit, due to the alternating magnetic field. The former is analagous to the iron-loss occurring in a direct-current motor, and for that reason may be called the direct-current iron-loss. It is supplied mechanically, its effect being to increase the frictional torque of the motor. The latter will be called the alternating-current iron-loss. This is supplied electrically by an increase in the energy-component of the voltage of both armature and field.

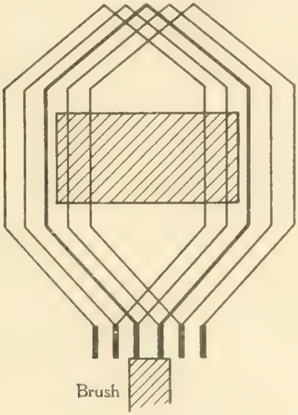


Fig. 3

(4.) THE COUNTER E.M.F. OF THE FIELD COILS—The three properties of the alternating-current motor, already considered, are chiefly of interest to those concerned with the design of the motor. For instance, the presence of an e.m.f. in the coil short-circuited by the brush introduces a problem for the designer to solve, and when he has solved it, its action is of no further importance. On the contrary, the existence of a generated e.m.f. in the field coils is a thing with which the man who operates the motor is very actively concerned. The field coil of the alternating-current motor is simply a choke coil, and has generated in it the familiar counter e.m.f. of self-induction. This counter e.m.f. affects the operation of the motor in two ways:

(a.) It introduces a voltage in the alternating-current motor that is not present in the direct-current motor, which increases the total voltage required to run the motor, particularly at starting. This voltage, however, is very nearly at right angles with the armature voltage, so that the different voltages are not directly added and subtracted; i. e., the numerical sum of the armature voltage and field voltage is not equal to the total voltage of the motor, as measured across the terminals.

(b.) It increases the seriousness of a short circuit in the field coil. With direct current a short circuit simply means cutting out the short-circuited turns; it does not usually put the motor out of service. With alternating current, however, it is obvious that this counter e.m.f. will cause a destructive current to flow in the short-circuited turns, burning them out and opening the motor-circuit. This is taken care of in the motor by additional insulation in the field coils.

A more detailed explanation of these effects can be made most clearly by a diagram of the motor voltages.

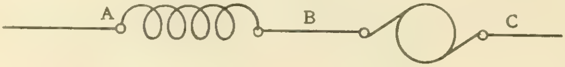


Fig. 4

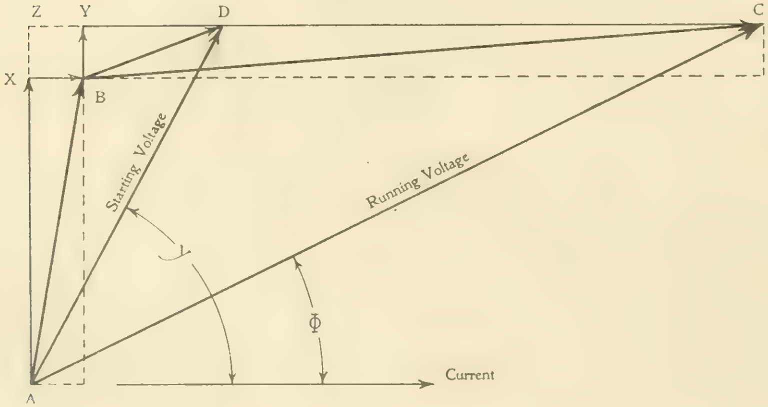


Fig. 5

Fig. 4 represents the motor circuit and Fig. 5 the voltage diagram. The two sketches are similarly lettered, so that the line A B in Fig. 5 represents the voltage of the circuit A B in Fig. 4. Starting at one terminal, A, and with the direction of current as shown, the field voltage is the line A B. It is made up of two components, the e.m.f. used in overcoming the counter e.m.f. of self-induction, A X, and the e.m.f. representing the losses supplied by the field, X B; or, in other words, of the inductive component, A X, and of the energy component, X B. It is seen that the energy component is small compared with the inductive component, which makes the field voltage nearly 90 degrees ahead of the current. The line B C is the armature voltage. This also is the resultant of energy and inductive components, B Y and Y C. In the armature, the energy component is the larger, since it represents, in addition to the armature losses, the energy transformed into mechanical work. It is also seen that the armature self-induction is small, compared with that of the field. The total voltage of the motor is A C, and is the resultant of the armature and field voltages. It is considerably smaller than their numerical sum. The total voltage is also the resultant of the total inductive component, A Z, and of the total energy component, Z C.

Since the motor is a series machine, the total inductive component is always the same for the same current; it does not depend on the impressed voltage or power developed. For example, in a shunt motor, the magnetizing current—and, therefore, the inductive voltage—would depend on the impressed voltage. Suppose that the motor is just starting, and is taking the same current as when operating under the conditions shown in the diagram, in which it is running at high speed and developing considerable power. Since the current is the same, the total inductive voltage is the same. The energy component of the field voltage is the same, but the energy component of the armature voltage is very much less, since on starting, the developed power is inconsiderable, although the torque may be the same. The total energy component approximates Z D, Fig. 5. Then, on starting, the motor voltage (the resultant of the total inductive and total energy components) is A D. It is evident that the field counter e.m.f. has a much greater effect on the total motor voltage on starting than when up to speed. With alternating current the starting voltage is about one-half the full rated voltage; with direct current in the same motor and under the same conditions the respective voltages would be approximately equal to the energy components Z C and Z D in Fig. 5. The relation, instead of one-half, would be about one-sixth. The power factor is also low on starting, as shown by the diagram, the angle y

representing the phase difference between voltage and current. This follows naturally from the fact that the inductive component is about the same as when the motor is loaded, while the energy component is very much smaller. It may be noted that the low-power factor at starting implies less power from the circuit than a high power factor. The angle Φ represents the phase difference under running conditions. The power factor on high speed is greater with small currents than with heavy currents, as the inductive e.m.f. of the field is less.

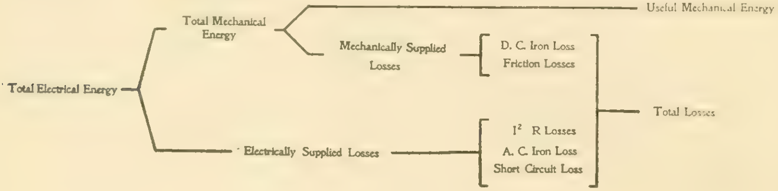


Fig. 6

The alternating-current series motor serves as a very interesting illustration of the fact, true of all motors, that certain losses are supplied directly from the electrical energy and others, indirectly, by the mechanical energy produced by the motor. The chart, Fig. 6, shows this more concretely, distinguishing these two classes of losses in the alternating-current motor.

THE ELECTRIC CLUB

AN ACCOUNT OF ITS ORGANIZATION AND OF ITS SOCIAL AND TECHNICAL DEPARTMENTS

By H. W. Peck, President of The Electric Club

In the works of the Westinghouse Electric & Manufacturing Company at East Pittsburg, where three years ago six thousand men were employed in the manufacture of electrical machinery and apparatus, there were, perhaps fifty apprentices working in the various departments. Most of them had completed a high school course in their education, some had attended technical schools or colleges, and a few had received engineering degrees from universities of high standing. The conditions of service of these apprentices, their object in view, and their aims were quite different; they were, however, banded together by many common interests, the chief being that they were working students.

THE READING ROOM

During the winter of 1900–01 a course of lectures covering a wide scope of engineering subjects was given by the engineers of the Electric Company, for the benefit of the apprentices, the foremen, the inspectors, and the testers. The lectures were prepared in accordance with the engineer's opinion regarding the composite intelligence and experience of this audience. The lectures were given twice a week in an office-room at East Pittsburg. In spite of the fact that most of the men lived in Wilkinsburg, six miles away, and had barely time to go home, eat dinner, dress cleanly and return to the Works between the times of quitting work and beginning of the lectures, the success of the course was indicated by the very large and regular attendance. During the following spring a certain number of the apprentices started a systematic inspection of the large power houses and industrial establishments about Pittsburg. In the summer this matter was taken up in a larger way for the benefit of all of the apprentices, and excursions were arranged to these places on many evenings, Saturday afternoons, and holidays. Occasionally these same men met together in the city simply for a good time, and to forget work in play, for they felt the need of recreation and had but little opportunity for it. It was the knowledge of these things that brought forth the idea of securing, conveniently located in Wilkinsburg, a hall in which could be given during the following season a course of lectures similar to that of the previous year. But the idea once formed showed itself protoplasmic and grew rapidly.

There was constant and increasing need in the commercial, engineering and production departments of the Electric Company for young men who had received both theoretical and practical training. The time might soon come when the majority of the apprentices would be college men not training to run a lathe or a milling machine or to do commercial testing, but studying modern methods of manufacture and the details of the construction and operation of electrical machinery. The idea grew, it grew until THE ELECTRIC CLUB was formed, and still it is growing.

Two hundred apprentices, many of them graduates of technical schools and colleges, sufficiently in earnest and with such interest in engineering as to spend two years working hard in the shops to learn the industrial part of their profession; several hundred other men, draftsmen of more or less experience with this and other companies, engineers of experience ranking in their specialties among the foremost; young men in the commercial and production departments, handling the same apparatus on paper and in manufacture; where could be found better conditions for the formation of a club, a serious club, composed of active members?

Club rooms were secured by the promoters and an invitation was sent to all of the apprentices and engineers of the Electric Company to attend a general meeting at which the organization of a club would be effected. One hundred and fifty responded and organized on March 19th, 1902, THE ELECTRIC CLUB, adopted a constitution, and elected members. The purpose of the CLUB is broadly stated to be "for social recreation, mutual benefit and improvement, and more particularly for the dissemination of electrical and engineering knowledge among its members." The government is vested in a board of nine directors, chosen from different departments. Members of the board of directors are elected to the official positions of President, Vice-President, Secretary, and Treasurer. The membership is limited to employes of the Westinghouse Companies. General committees are appointed by the board to take charge of the various activities of the CLUB. The duties of the House, the Lecture, the Library, the Reception, the Athletic, and the Publication Committees are the same as usually pertain to such committees.

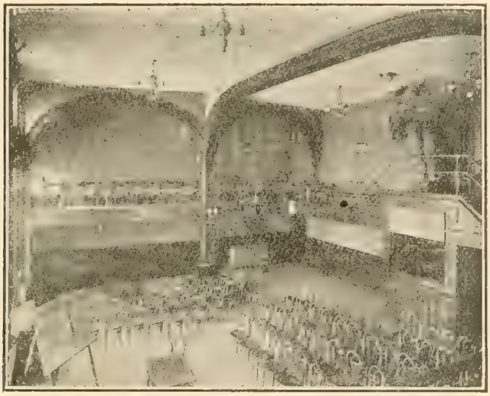
A MEETING ROOM

The Section Committee arranges the organization of those members who wish to undertake the study of any certain line of engineering. These organizations are termed sections. The Excursion Committee provides information regarding industrial establishments, power houses and other places of interest and, when passes are necessary, secures them for members desiring to visit these places.

The CLUB has been a success from the start, continually learning to adapt itself for further advantage to its members, learning by the experience of one season to be more efficient the next, and growing rapidly in numbers. There are now enrolled over five hundred members, representing the Westinghouse Electric & Manufacturing Co., the Westinghouse Machine Co., the Westinghouse Air Brake Co., the Union Switch & Signal Co., the Nernst Lamp Co., the Westinghouse Foundries Co.; representing seventy-two colleges and technical schools, many countries, and experience of most varied scope.

The club rooms occupy the entire second floor and part of the third floor of the Hamnett Building, 735–737 Penn Ave., Wilkinsburg, a location on the outskirts of Pittsburg convenient to the members, most of whom reside in Wilkinsburg. Considerable work was done upon the rooms to adapt them to the requirements of the CLUB, which they now meet admirably. They are furnished comfortably and tastefully, are lighted by Nernst lamps, and the walls are adorned with appropriate pictures. The assembly hall, with balconies, has a seating capacity of about three hundred. Here the members gather once or twice a week for lectures, some technical, some general. Most of the lecturers are Pittsburg men, but frequently visitors to the Company consent to spend an evening at the CLUB, where they talk to an unusually homogeneous and interested audience. A projection lantern and screen are available whenever the lecturer wishes to illustrate his lecture, and when desired a blackboard can be used.

Once a month the Pittsburg Local Branch of the A. I. E. E. meets in the hall and the club members are invited to attend and participate in their valuable and interesting meetings. The discussions regarding the Institute papers are usually entered into earnestly and much additional information upon the subject-matter is given. In this hall also the members satisfy their lighter interests with music, exercise, and bi-weekly entertainments and dances. The reading room is a large, well-lighted room, furnished with more attention to comfort than are the other rooms, and it is here that the men assemble every evening to talk and smoke socially together, to occupy a Morris chair with an interesting magazine, or an arm chair by a table with a technical journal. Here they pass a pleasant hour after dinner, between the work of the shop and the work of the section, to enter the latter with keener mind and greater appreciation. On file here are nearly all the technical journals and in the book case is a small reference library. The other rooms are smaller and are equipped with tables and blackboards, adapting them especially for the section meetings. From fifteen to seventy men attend to hear the presentation of a particular phase of the subject, often by a member of the section, and then to question and discuss the matter together under the guidance of the leader of the section, who is an experienced engineer in that branch. It is the work of these sections that connects the theory of the college with the "labor and material" of the shop, and more than this: it reviews, broadens, and applies the theory, it instructs and explains in connection with the design, the shop work and the use, points which the workman or the student would never observe. Preparation is made for these sections, for although there is no school discipline, there is the real interest and appreciation of the section work which keeps it in the minds of the men during their shop work and during their reading.



THE ASSEMBLY HALL

The men bring to these meetings considerable experience, knowledge obtained in college, or from books and journals, and inquiring minds. The leaders are engineers who, during their several years' service with a leading electric company, have had unsurpassed opportunities for keeping in touch with the foremost practice, not only of their own company, but of other companies and engineers. As it is possible for a club member to attend but few of the many sections, the extensive work done for each has been of value only to those who have attended that section. Now, however, THE ELECTRIC CLUB JOURNAL will publish that which is best and newest in the work of the sections and thus preserve it in convenient form for many.

The general excursions arranged by the committee have proved very popular and the best attention has been given to the members by the establishments visited. Under the present regime a number of smaller parties have been organized for excursions, and the club members appreciate the interest and value of the information that can be obtained by familiarity with the industries of the Pittsburg district, and the additional facilities afforded them through the CLUB.

Aside from the "ladies' nights" in the hall, whist, chess, checkers, fencing, boxing and an orchestra afford indoor entertainment and recreation for those so inclined, while an athletic field affords opportunity for baseball, tennis and football during the season of outdoor life.

It is not well, physically, intellectually, or morally for men to be alone. Association with others is always the best way to bring out the most in a man, to effect the greatest accomplishments from each one and from all together. They encourage each other, instigate the weaker ones to greater endeavor, and create a mental atmosphere favorable to their pursuits. This is the well-known principle which insures the success of a club organized under such favorable conditions as THE ELECTRIC CLUB.

THOMAS CYPRIAN FRENYEAR

By W. M. McFarland

THAT the leading positions in the electrical industry are largely filled by young men is forcibly brought to mind by the recent death of Mr. Thomas Cyprian Frenyear, Sales-Manager of the Canadian Westinghouse Company, Limited, which occurred at Fort William, Canada, December 10, 1903, before he had attained the age of thirty-nine.

Mr. Frenyear was born March 16, 1865, at Middletown Spa, Vermont. Like many other men who have attained positions of prominence, he was the son of a country clergyman, his father, the Rev. C. P. Frenyear, being a minister of the Baptist Church. Much has been said and written of the advantages of adversity, and those who know the extremely moderate salary of the average country clergyman can appreciate that the children of such a family are certainly not handicapped by the enervating influence of wealth and luxury. We often hear the sneering remark that clergymen's sons are noted for turning out badly, but Mr. Frenyear was one of the numerous cases which prove that this sneer is very largely without foundation, and that the remark is really magnifying the exception into the rule.

From an early age Mr. Frenyear displayed unusual mental ability, although he did not go to school until the age of ten, receiving his instruction at home from his mother until that time. When the family moved to Townsend, Vermont, he entered Leland and Gray Seminary, where he was in classes with boys of sixteen and eighteen years of age, with whom he more than held his own, thus showing remarkable mental development in one so young. His schooling continued until he was about fifteen, when he entered the office of an uncle, Mr. W. R. Nutting, Manager of the Boston Electric Company. Although starting thus early in a business career, he did not give up his school work, but entered the Boston Latin School, where he maintained his class standing by devoting all his spare time to study. From the Boston Latin School he went to Phillips Exeter Academy, where he graduated in 1885. As showing his grit and determination, it may be mentioned that he supported himself while at Exeter by keeping a book-store for the students.

Shortly before leaving the Academy he took an examination for Harvard, which he passed with credit, and he entered the University in the autumn of 1885. At this time he was engaged in business with two of his classmates, with an office in Boston. He found, however, that it was impracticable for him to continue at Harvard, because he could not spare the time to go back and forth from his office to recitations. He then entered Boston University; but, through the fault of one of his partners, their concern was wrecked, and he was obliged to leave the University.

Probably on account of his touch with electrical affairs, through the work in his uncle's office (already mentioned), he went into the electrical industry and, for a time, was a salesman for the Thomson-Houston Company and the Brush Electric Company, with headquarters at Buffalo. He left that company to become Superintendent of the Cayadutta Electric Railway, which position he held from 1892 to 1895. In the fall of 1895 he entered the employ of the Westinghouse Electric & Manufacturing Company.

In 1897 he was made Manager of the Buffalo office of the Westinghouse Company, where he displayed marked ability and built up a large business. The location of his office and inclusion of a large amount of Canadian territory within its district gave him a large experience in Canadian business, so that he was well equipped on the formation of the Canadian Westinghouse Company, Limited, to take the position of Sales-Manager, to which he was promoted. He entered upon this work with enthusiasm, and had the affairs of his office splendidly organized when he was stricken down with typhoid fever, from which he died after lingering a few weeks at Fort William, where he had gone on business. His whole career had shown him to be a man of great ability and strong character, and there can be no doubt that a most promising career was cut short by his untimely death.

The religious side of Mr. Frenyear's character was strongly developed, and while he never forced his views upon his associates, they all knew his convictions and respected them. He joined the church at the early age of eleven years, and was always an active member. While in Buffalo he was a deacon and trustee of the Delaware Avenue Baptist Church, and was at one time superintendent of its Sunday School. He was also a very active worker in the Young Men's Christian Association.

Mr. Frenyear was a man of culture, and very fond of the standard classical authors. A lecture which he delivered less than a year ago before the Electric Club at Wilkinsburg, Pa., is notable for its literary excellence and the wide acquaintance with the great writers which it shows.

In June, 1893, he married Miss Emma L. Chase, of Exeter, the daughter of a Baptist clergyman, who now survives him with three young children, one of whom is only a few months old.

Mr. Frenyear was a man of very agreeable personality, although quiet and undemonstrative; but as one became acquainted with him his sterling qualities were more fully appreciated, so that acquaintanceship ripened into sincere regard. His death came as a shock to all his friends, who had rejoiced in the wider field opened to him by his new position, and were counting on an increased reputation for him. As a mark of the high regard in which he was held by the Westinghouse Electric Company, the senior Vice-President, Mr. Frank H. Taylor, issued a circular letter, appreciative of his ability and zeal, and expressing the sorrow felt at his death and the deep sympathy of everybody for his family.

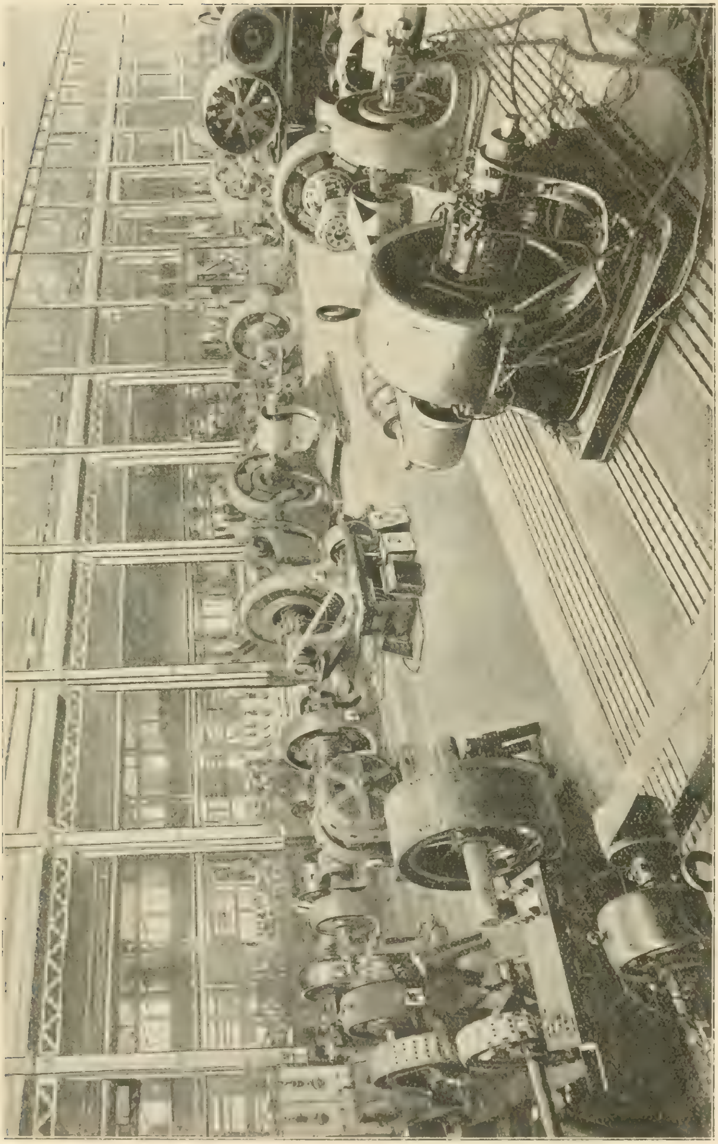


FIG. 1—THE MAIN AISLE OF THE TESTING DEPARTMENT OF THE ELECTRIC COMPANY

FACTORY TESTING OF ELECTRICAL MACHINERY

I. INTRODUCTION: ORGANIZATION, WORK, AND EQUIPMENT OF THE TESTING DEPARTMENT

By E. R. Cross and R. E. Workman

ORGANIZATION

THE position which the testing department occupies in any works-system is an important one, for upon its efficiency largely depends the quality and reputation of the product of the works; and this importance of the testing department is increased in the case of an electrical manufacturing company by reason of the technical ability and experience required of its men.

The two important functions of the electrical testing department are: first, to furnish the engineering department with information regarding the operation of machines so that the design can be checked with the actual performance; and second, to maintain, in the company's interest, a high standard of workmanship and material in the factory. These two functions correspond roughly with the two classes of work in the department—experimental and commercial—which are explained more fully in a subsequent paragraph.

The testing department is a department of the factory and its administration is ultimately under the control of the Manager of Works; its work, however, is directed by the engineering department, i. e., the engineer specifies the tests to be made and the results, in the case of first machines of a new type, special machines, and all large machines, are submitted to him in the form of curves, his approval of the curves being necessary before the machines can be "passed" for shipment. These curves are systematically filed for future reference, so that, in the case of duplicate machines of small size, the results of tests have simply to be compared with those of the first machine of its type, and, if it checks sufficiently well, the machine is passed without reference to the engineer. The engineer, however, having passed the curves on the first machine of the type, is indirectly responsible for the satisfactory performance of duplicate machines after they have been passed for shipment. A general foreman is directly in charge of the administration of the department, and is responsible for the accuracy of all testing work. The working up of tests is entirely separate from the actual work of testing, and is done by different men. The testing floor is in charge of an assistant general foreman and, under him, of three foremen, each foreman having charge of a section of the department. Under the foremen are testers who are responsible for individual tests and who have assistants to help in the necessary work. The calculating office is in charge of a chief who has under him men to do the required calculating and plotting of curves. Practically all of the men in the calculating office, most of the assistant testers, and a few of the testers are engineering apprentices.

CHARACTER OF WORK OF THE DEPARTMENT

The work done by the testing department may be classified under two general heads: EXPERIMENTAL and COMMERCIAL.

(a) EXPERIMENTAL TESTING—This includes the work on all new or proposed designs of apparatus, on which it is desired to obtain information regarding operation under test and to prove or determine correctness in design. The tests commonly made for this purpose are summarized in Table I.

TABLE I. EXPERIMENTAL TESTS.

	DETERMINED BY	TEST REQUIRED.	REMARKS.
Rating.	(1) Heating.	(1) Temperature Test	These tests are made on all machines—D. C. and A. C.
	(2) Drop in { Voltage. Speed.	(2) Reg'l't'ns { e.m.f. Speed.	
	(3) Commutation.	(3) Commutation Test	(3) On D. C. machines only.
Efficiency.	(1) Direct relation between output and input.	(1) Brake Test.	(1) This test is made only on motors, A. C. and D. C.
	(2) Magnitude of losses.	(2) Loss Tests.	(2) Made on all machines.
	(a) Copper loss.	(a) Resistances.	
	(b) Iron loss.	(b) Iron loss and saturation.	
	(c) Friction losses.	(c) Friction Test.	
Insulation.	Resistance to breakdown at high A. C. voltage.	Puncture test.	Made on all machines.

The meaning of the table may be explained by following through one of the items; thus, RATING is determined, among other things, by DROP IN VOLTAGE in a generator, or DROP IN SPEED in a motor. For their determination, the tests required are E.M.F. REGULATION and SPEED REGULATION, respectively. These regulation tests are made on all machines, both alternating and direct-current. The table will be found to cover the range of tests commonly made.

Mechanical considerations also play a prominent part in the successful operation of a machine, particularly as defects of this kind may be so inconspicuous as to escape ordinary notice until the machine is put in operation. Features of mechanical design are generally standard for machines of a given type, the main consideration being that the structure shall readily accommodate the windings, provide the necessary means for effective lubrication, and have the bearings properly proportioned for supporting the pressure of the rotating part. The finished machine should also, in addition to doing its work, present a pleasing appearance to the eye, a point not to be lost sight of in the midst of the purely useful details of construction. Above all, the apparatus should have sufficient strength, mechanical as well as electrical, to withstand the various stresses to which it may be subjected in the course of actual service. Most mechanical defects will show up in tests made primarily to prove the electrical design, as outlined in Table I. Others can be detected only by long-continued operation of the machine under actual service conditions. For these reasons specific tests for detecting mechanical defects in new designs are not usually made.

(b) COMMERCIAL TESTING—This includes the work on all machines which duplicate previous designs, and its purpose is, simply, to prove correct manufacture. With the complete series of curves and records of tests which have been made on the first machine of all designs, it is an easy matter of reference to check any detail of performance desired, and tell whether any particular machine of old design is "up to standard" or not.

Correct manufacture, the maintenance of which is the object of commercial testing, involves the absence of the defects summarized in Table II.

TABLE II. DEFECTS IN MANUFACTURE.

CLASS OF DEFECT	DEFECT IN	TEST TO DETERMINE DEFECT	DEFECT SHOWN BY
Defective Material.	Sheet steel.	(a) Iron-loss. (b) Temperature Test.	(a) Excessive iron-loss at normal excitation. (b) Excessive temperature of iron.
	Insulation.	Puncture Test.	Breakdown of insulation.
Defective Workmanship.	Assembling core.	(a) Iron-loss. (b) Temperature Test.	(a) Excessive iron-loss due to poor insulation between laminations. Humming due to loose assembling. (b) Excessive temperature of iron. Humming.
	Insulating coils.	Puncture Test.	Break-down of insulation.
	Spacing poles or spacing brushes.	(a) Saturation. (b) Temperature Test. (c) Iron-loss.	(a) (b) Persistent sparking of brushes not in correct position. Not remedied by shifting brushes. (c) Excessive loss in brushes due to wrong position.
	Size of air-gap.	(a) Saturation. (b) Temperature Test.	Wrong speed or e.m.f. (motor or generator).
	Short circuit in armature.	(a) Saturation. (b) Temperature Test.	Local heating in short-circuited coils.
	Open circuit in armature.	(a) Regulation. (b) Temperature Test.	Flashing at all of the brushes successively as open circuit passes under brush.
	Bearings.	Any running test.	Excessive heating.
	Balance.	Any running test.	Vibration.
Defective Assembling.	Wrong armature.	(a) Saturation. (b) Temperature Test. (c) Resistance.	(a) (b) Wrong speed or e.m.f. (c) High or low armature resistance.
	Wrong field coils.	(a) Saturation. (b) Temperature Test. (c) Resistance.	(a) (b) Wrong speed or e.m.f. (c) High or low field resistance.
	Reversed field coil.	(a) Saturation. (b) Temperature Test. (c) Polarity.	(a) (b) Wrong speed or e.m.f. (c) Not alternate N. and S.

From this table it is seen that all defects in manufacture (except in insulation) will show up in the temperature test. Further tests, however, may be necessary for their complete identification. Accordingly, the commercial test for small machines is a temperature test, which includes voltage or speed regulation, followed immediately by an insulation test. With larger machines the temperature test may be replaced or supplemented by other tests given in the table.

EQUIPMENT OF TESTING DEPARTMENT

POWER SUPPLY—The power available in the testing department must be of sufficient range in voltage for direct current, and in frequency for alternating current to cover the voltages and frequencies of the motors, and other apparatus requiring electrical power, that come to the department for test. The equipment of the department includes the following sources of power:

Direct-Current.

(1) 500-volt, direct from power-house.

(2) 220-volt, from 220-volt rotary converter driven by 3000 alternation alternating current from power-house.

(3) 110-volt, from 110-volt generator coupled to induction motor which is driven by 3000-alternation alternating current from power-house.

In the different sections of the department there are smaller direct-current machines which may be used as boosters for voltage regulation or as sources of power for tests of small machines.

Alternating-Current.

There are three sources of alternating current.

(1) Power-house, two-phase, 3000-alternation.

(2) 400-kw alternating-current generator two or three-phase, any frequency up to 8000 alternations, driven by 500-volt direct-current motor.

(3) 180-kw alternating-current generator, two-phase, 7200 alternations, driven by 500-volt direct-current motor.

Three-phase power is obtained from two-phase by transformers and single-phase from one phase of the two-phase.

Different voltages are obtained by transformers, by means of taps in their secondaries as well as by different arrangements of connections.

POWER DISTRIBUTION—Power is distributed from the various generators to terminals conveniently located throughout the department. In the main aisle, where the large work is done, these terminals are located in pits, the necessary cables being carried through subways. For the smaller work the wiring is carried overhead and the terminals are located just beneath the controlling switchboards. In the case of the 500-volt direct-current terminals connected directly with the power-house each set is controlled by a switchboard panel containing positive and negative line switches, an ammeter and circuit-breaker, a field rheostat and terminals for connecting in a motor-starting rheostat. The terminals for the 220-volt and 110-volt circuits are all controlled from a central distributing switchboard, each set of terminals having simply a double-pole line switch. The circuit-breakers and ammeters are located on the generator switchboard in the department. Circuit-breakers are also provided on the testing tables, the controlling idea being to prevent troubles that develop in the testing circuits from affecting circuits outside of the department.

Alternating-current power is distributed from a power-board containing the 400-kw generator line and field switches, and the necessary feeder or "relay" switches. The 180-kw generator may be connected with the power-board by means of either of two relays, a high-tension and a low-tension, either directly or through transformers. Power from the alternating-current shop circuit comes to the department through a panel on the power-board containing circuit-breakers, line switches and relay switches, by means of which it is connected to the distributing system. From the power-board each of these three sources of power may be connected to a relay board, whence, by a convenient arrangement of switches, it may be relayed to the various pits in the main aisle.

Testing tables containing the necessary switches and terminals for the instruments are universally used. In the larger work these tables are portable and are carried to the machine to be tested by the cranes. They are then wired up to the machine and to the proper pit for the test to be made. In the small work the tables are stationary and the machine under test is brought to the table.

Measuring Instruments—It is not intended to give a description of the various instruments used in the testing department—they are all well-known standard instruments, and their construction is illustrated in the elementary text-books. Attention will be confined to matters affecting their use.

Direct-Current Ammeters—Ammeters are always provided with a short-circuiting switch which is part of the permanent connections of the testing table. This switch is closed except when the ammeter is being read. Its use enables the instrument to be put in and taken out of the circuit with the current flowing, and prevents the instrument from heating up if it is left in circuit during a long temperature run.

Direct-Current Voltmeters—Voltmeters are usually connected in the circuits by means of leads provided with metal points at one end. Too much care cannot be exercised in the use of voltmeters, especially in the case of those with low-reading scales. When using voltmeters with high and low scales for small drops, it is always best to try the high scale first, and then if the reading is within the range of the low scale, to change over to the low scale.

The range of direct-current voltmeters may be increased by adding resistances to the voltmeter circuit having known relations to the voltmeter resistance. The addition of resistance will decrease the current in the voltmeter circuit, and therefore the voltmeter reading, in the ratio of the voltmeter resistance to the sum of the voltmeter resistance and the added resistance. This follows directly from Ohm's Law.

No instrument measuring either current or voltage in direct-current circuits should be placed nearer a field magnet than five feet, and should be kept away from all cables carrying large direct currents. In the case of instruments of the permanent magnet type, not only is the reading affected by the stray field, but the calibration of the instrument may be permanently altered, due to a change in the strength of the magnet. In the case of instruments of the dynamometer type, the reading is much more largely affected, but the instrument is not permanently injured. If great accuracy is desired or in cases where stray fields are strong and unavoidable, in measuring current in direct-current circuits by means of instruments of the dynamometer type, the effect of stray fields may be eliminated by taking the mean of two readings, read before and after reversing the leads to the instrument.

Alternating-Current Voltmeters—Alternating-current voltmeters are used in exactly the same way as direct-current voltmeters. Resistance multipliers used with alternating currents must, of course, be very nearly non-inductive. It must also be remembered that, though the inductance of these multipliers be but small, the presence of stray fields of the same periodicity as that of the circuit may produce quite an appreciable inductive "drop" in their length. There is a certain amount of self-induction in the voltmeter coil; this will have no appreciable effect on the accuracy except on high frequency with low-reading instruments, in which the non-inductive resistance is necessarily small. Transformers supply an accurate and convenient means for extending the range of the voltmeter providing the transformer is operating under conditions approximating those for which it was designed. A transformer designed for 200 volts maximum will not be very accurate on 5 or 10 volts maximum; or a 7200-alternation transformer will not be satisfactory on 2000 alternations. It is usually a simple matter to roughly check the ratio of 2 to 1 or 4 to 1 transformers by successive readings with and without the transformer; this should be done if there is any doubt about the correctness of the ratio.

Dynamometers—Current dynamometers are used in the testing department of the Electric Company to the almost entire exclusion of other forms of alternating-current ammeters. The advantages of the dynamometer type are:

(1) It may be used as accurately with direct current as with alternating current, if care be taken, in both cases, to eliminate the effects of stray fields by taking the mean of two readings, read before and after reversing the leads to the instrument.

(2) It is practically independent of frequency and wave form.

(3) It has an independent division of scale.

(4) It has a simple and open construction.

The disadvantages of an instrument of this type are:

(1) The torque is very small compared with the weight of the moving element. This means that a much weaker spring has to be used than in other types of alternating-current ammeters, introducing greater errors from friction, and impairing the permanency of the calibration.

(2) It is not direct reading, the current being obtained by the equation $I = k\sqrt{d}$; where k is the constant of the instrument, determined by calibration and d the deflection.

In using dynamometers, or in fact any alternating-current instrument, it should be remembered that the accuracy is affected by stray fields OF THE SAME FREQUENCY as that of the current measured. Stray fields are often due to currents in the main cables, especially if the cable is resting on an iron bedplate. The presence of stray fields can be detected by taking a check reading with the dynamometer turned through 180 degrees, or with the leads reversed.

Indicating Wattmeters—The Weston indicating wattmeter is merely a watt-dynamometer. Instead of having coils in series, as in the current-dynamometer, there is one series coil and one shunt coil.

It may be proved that the torque on the moving coil of the wattmeter is proportional to the product of the effective values of current and voltage and the cosine of the angle of lag of the current behind the voltage. This quantity is the actual power expended in the part of the circuit across which the voltage coil is connected. If, as in direct-current circuits, a reading be taken with an ammeter and one with a voltmeter, the product of the resulting quantity will be proportional, simply, to the product of the effective values of current and voltage, which is not the true power. In the use of the wattmeter there is an additional factor that affects its accuracy: the phase relations in the instrument. The relation between the phases of the currents in the series and in the shunt coils must be the same as that between the phases of the current and the terminal voltage of the part of the circuit whose power is being measured. This phase relation in the wattmeter circuits may be changed from that in the outside circuit in two ways:

(1) By the inductance in the shunt coil of the wattmeter;

(2) By a change in the phase of either series or shunt currents, owing to the use of instrument transformers.

The former cause being inherent to the instrument itself and usually negligible, does not concern us. In regard to the latter, there is always a difference in phase between primary and secondary currents and voltages in series and shunt transformers, respectively, and, unless these differences are known to be small, a considerable error may be introduced in the wattmeter reading. This cause of error is more often present in a testing department than in a power-house, where the circuits are permanent and the instrument transformers are designed for definite service. Transformers are designed for a certain degree of accuracy, both in phase position and in ratio, only within a certain range of load and for a certain frequency. When used for greater or smaller loads, or with smaller frequencies, considerable error may be introduced. Therefore the frequency and percent load, as well as the ratio, should be considered in selecting a transformer for a particular test.

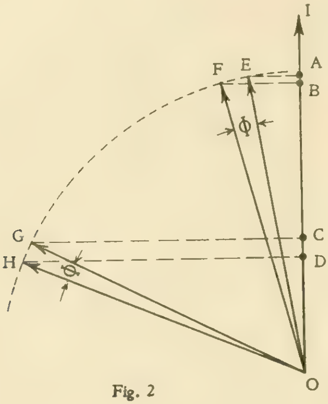


Fig. 2

This difference in phase relation between the outside circuit and the wattmeter circuit is of much more importance with low power-factor than with high. The reason for this is plainly shown by the diagram (Fig. 2). O I represents the current and O H and O F represent the positions of the voltage in the outside circuit for a high and low power-factor. O G and O E represent the positions of the current in the shunt coil of the wattmeter corresponding with the voltages O H and O F. These currents lag behind the voltage by the same angle Φ. It is plain that this angle has much more influence on the measured power (proportional to the projections of O G and O E on O I) with a low power-factor than with a high power-factor. It is also seen that the measured power (O I x O A) is greater than the true power (O I x O B); that is, the wattmeter reads high on low power-factor.

THE NEW EAST SHOP OF THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

By C. C. Tyler, Superintendent

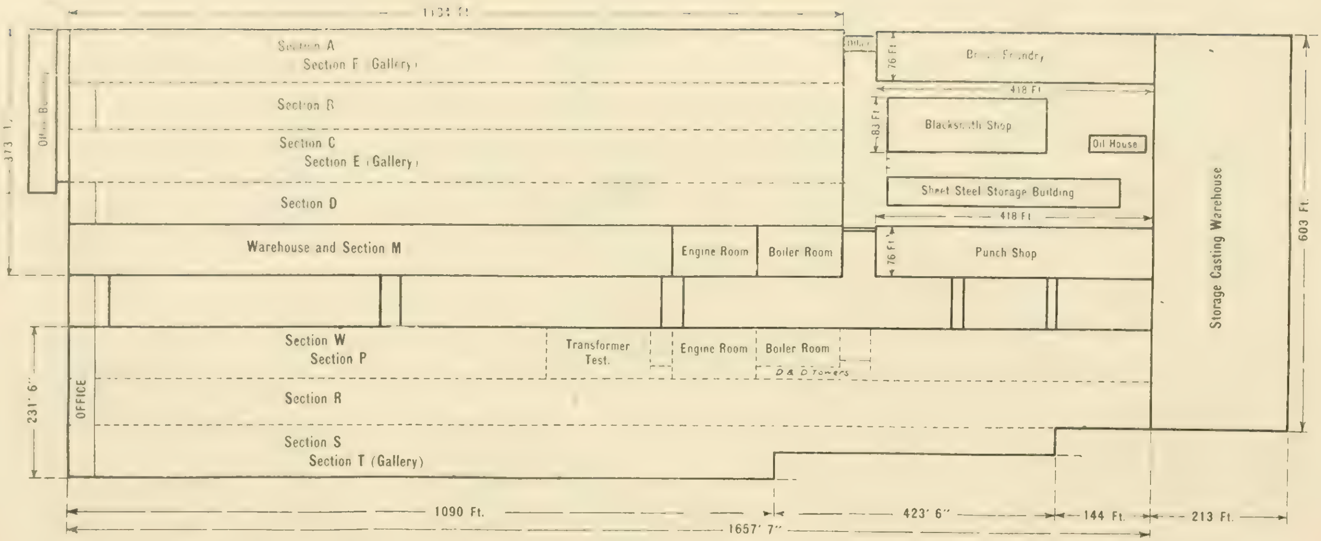
THE writer was recently requested to prepare an article giving an outline of the plan for utilizing the floor space of the New East Shop, and has consented to undertake it, believing the subject to be of interest to the readers of THE ELECTRIC CLUB JOURNAL.

It is said to be the largest single building ever erected for manufacturing purposes, and as a complete description of it, together with photographs and plans, will probably be published in some of the technical trade papers, a brief statement covering its principal dimensions must suffice for this article.

The total length of the building is 1,658 feet; it has a width of 230 feet for a length of 1,082 feet from the south wall; a width of 190 feet for a length of 423 feet, and a width of 150 feet for the remaining 144 feet of length—the reduction in width affecting the ground and gallery floors of the east aisle only. The east end wall of the casting store-house is joined to the east shop, making a continuous east wall, having a total length of 1,868 feet, or more than one-third of a mile.

In general plan the design of this building closely follows that of the original main machine shop, there being a central aisle, constituting a high bay, and two side aisles, each having a ground and gallery floor. The central bay is 70 feet wide, and is unobstructed for its entire length of 1,658 feet, except for a drawbridge 33 feet wide, approximately in line with the present drawbridge in Section D. The ground and gallery floors of the east side aisle are 80 feet wide for 1,082 feet, and are 40 feet wide for 432 feet—both unobstructed by partitions. The ground and gallery floors of the west side aisles are 80 feet wide for the entire length of 1,658 feet; both of these floors are obstructed by the partition walls enclosing the power-house, to which reference will be made later.

The East Shop is connected with the older buildings by seven bridges. The two bridges north of the power-house are 16



WORKS OF WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, EAST PITTSBURG, PA.

Sections P, W, R, S and T comprise the new East Shop—Sections A, F, B, C, E, D and M comprise the Main Shop Sections run north and south with the office buildings at the south end of the works.

feet wide. The two bridges connecting the two power-houses are 6 feet and 8 feet wide; one of these carrying steam pipes and the other a coal conveyor. The two bridges next south of the power-house are 32 feet wide, and the bridge at the south end of the building is 64 feet wide and has two floors. All of the bridges, except the power-house bridges (which are higher), connect the shops on a level with the gallery floor, thereby permitting the passage of inter-works and freight trains without interference.

The main entrances to the East Shop are at the south end in the center of the building, on the ground and gallery floor levels. For a distance of 48 feet, each side of the entrances, and upon both floors of the south bridge, are located a number of offices, the present large office building having proved inadequate for the requirements of the business of the Company. There are three office floors over the entire width of the building and a fourth floor the width of the central high bay; the offices being finished in a style corresponding with those in the large office building. These offices have been allotted to various departments as follows:

Ground floor, east, Publishing Department; ground floor, west, Specification Department; first or mezzanine floor, east, Detail Engineering Department, Office Division; first floor, west, Purchasing Department; second or gallery floor, east, Superintendent's Office; second floor, west, Production Department; third floor, center, Engineer of Works' Office; south bridge, both floors, Detail Engineering Department, Drafting Division.

Following the practice in the Main Shop, the five aisles of the East Shop will be known as Sections, each having been assigned a characteristic letter in this order: West aisle, ground floor, Section P; center aisle, Section R; east aisle, ground floor, Section S; east aisle, gallery floor, Section T; west aisle, gallery floor, Section W.

The increased production which will be called for when the East Shop is in operation made it necessary to provide for large extensions to many of the existing departments in the Main Shop, and in the allotment of space in the East Shop much attention was given to caring for these extensions and so to locate departments that the transportation of materials would be reduced to minimum distances. The cost of manufacturing operations was the paramount issue; the cost of transportation being next in importance because of the long distances between

The East Pittsburg Works of The Westinghouse Electric and Manufacturing Co.

departments due to the size and grouping of the buildings.

The lines of manufacture determined upon for the five new sections of the East Shop are as follows:

Section P. South of the power-house division wall, this section will be utilized for the manufacture and test of all sizes of O. D., Type N, oil insulated and air cooled transformers and static interrupters, and, until the space is needed for manufacturing purposes, this apparatus will be prepared for shipment, boxed and stored within the section—the actual loading on cars being also provided for at the south end of the section.

The transformer testing department is to be located in the space south of the power-house for the entire width of the section by 192 feet long and enclosed by brick fire walls with arched ceiling, making the department as nearly fireproof as possible.

Within the walls enclosing the transformer testing department, a space 64 feet by 80 feet has been allotted to the Electrical Engineering Department for experimental determinations. This space is separated from the Transformer Testing Department by a brick wall 8 feet high, over which electric traveling cranes can pass to make the necessary lifts of apparatus. A small room has been provided in this space, having partition walls extending from the floor to the ceiling, in which experimental tests may be made upon detail apparatus designed for operation upon very high tension lines.

The power-house is located in Section P, and the north and south brick partition walls extend up to the roof through Section W. The east side wall extends from the ground to the roof, separating the power-house from Section R; the whole space so enclosed being approximately 312 feet by 80 feet. The engine and generator room occupies 128 feet by 80 feet; the boiler room and stack room, 184 feet by 48 feet. The boiler room is separated from the engine and generator room by a brick partition wall extending from the basement up to the roof, and there is another full height brick partition wall on the east side of the boiler and stack rooms—there being no gallery floor over the boilers. That portion of the roof over the main enclosure of the power-house is made of concrete and the gallery floor within the power-house is supported by heavy steel girders and brick arches. A description of the power-house equipment will probably appear in a later issue of this JOURNAL.

Between the east wall of the boiler and stack rooms and the east wall of the power-house, separating it from Section R, approximately 184 feet by 32 feet, provision has been made for the erection of 12 towers for the treatment of insulating materials by a continuous process—these towers being considered a part of the extension of the dipping and drying department.

The space north of the power-house, Section P, will contain the tinners', pole piece and cutting-off departments.

The tinners' department will continue the manufacture of transformer tanks, field coil cases and other sheet metal work as heretofore, and the decision to locate this department here was based on its close proximity to the transformer department.

The pole piece department was located here to be near the punch department, from which it receives most of its material. The deliveries of finished pole pieces from this department will be made to Sections A, B, C, D, R and S, and to the store-keeping and shipping department.

The cutting-off department is an entirely new department, in which it is proposed to cut cold rolled steel, axle steel and tool steel for all departments of the works requiring material of this character cut to definite lengths. The stock of material required by the cutting-off department will be carried in the casting storehouse extension, to which reference will be made later.

The removal of the tinners' and pole piece departments from their old to this new location will provide ample space for the extension of the punch, annealing and sheet steel painting departments of Section G. The cutting-off department and the storage of the materials required by it in the casting store-house will make available space in the blacksmith shop, Section H, for additional forging fires.

Section R. This entire section will be utilized for the manufacture, test and shipment of all classes of A. C. and D. C. generators and motors, rotary converters, and apparatus having rotor and stator elements, excepting street railway motors, from 100-hp. up to machines having a maximum internal bore not exceeding six feet. This section will later relieve Sections B and D of the smaller apparatus they now manufacture, and for which their equipment of machine tools is not so well adapted as that to be located in Section R. By limiting the size of apparatus to be manufactured in this section to a definite diameter of maximum bore of the stationary parts, the maximum sizes for the machine tool equipment were immediately determined. The largest planers will take 10 feet between uprights; the largest boring mills will swing 10 feet between housings, and the largest lathes will swing 6 feet. The new machine tools for this section which have been purchased, were selected with due regard for the use of high speed cutting tool steels, and are all of very heavy pattern to meet the unusual requirements. The special equipment of machine tools for the manufacture of turbo-generators will probably be located in this section.

Section S. This section will differ from any other ground floor section in that but little of its product will be completely assembled within the limits of the section. It will in the main supply Sections A, B and C with parts ready for assembling, and its space will be apportioned among six new departments; namely, Frame, Bracket, Spider, Building, Shaft, and Bearing Departments.

The Frame Department will perform all machining operations on frames used in the manufacture of all alternating-current and direct-current apparatus now made in Section C, and its product will in most cases be ready for assembling operations when it leaves the department.

The Bracket Department will perform all machining operations upon all brackets used in connection with the product of the Frame Department.

The Spider Department will perform all machine operations upon all spiders used in the manufacture of all alternating-current and direct-current apparatus now made in Sections A and C, and its product will be delivered to the building department.

The Building Department will build sheet steel upon all shafts and spiders for the rotors required for the apparatus manufactured in Sections A and C. It will build sheet steel within all frames as required by Section C. It will also file the slots preparatory to winding in the sheet steel which it has built up on rotors and stators.

The Shaft Department will perform all machining and finishing operations upon all shafts required by Sections A, B, C, D and R, which are less than 8 inches diameter by 8 feet long, and provision has been made for finishing the parts of shafts having circular cross-section by suitable grinding machines. All shafts within the maximum size given will be made by this department to meet the requirements of the storekeeping and shipping department and of the detail and supply department.

The Bearing Department will perform all machining and finishing operations upon all bearings required by Sections A, B, C, D and R, which have a bearing surface less than 8 inches in diameter. It will also supply the storekeeping and shipping department and the detail and supply department with the bearings required by them to fill their orders.

The establishment and operation of the departments of Section S will change the character of the work now carried on in Section C, and later Section C will comprise four departments, namely, detail, assembling, winding, and testing departments.

The detail department will make the smaller parts required in the manufacture of alternating-current and direct-current generators and motors under 100-hp. now made in Section C, such as covers, resistance rings, auto-starters for Type H motors, etc.

The other departments will carry on similar operations to to those now being performed, only on a larger scale.

The vehicle motor department, Section F, will be absorbed into the departments of Sections C and F.

Section T. This section will be utilized exclusively for the manufacture of detail apparatus. The various departments now in Section M will be transferred to this section, with the exception of the screw and instrument departments.

The names of the various departments in Section T so far determined are—rheostat, switch, milling, oil switch, circuit breaker, marble working, switchboard, and detail testing departments. The removal of these departments from Section M will make that space available for an extension to the storekeeping and shipping department, provide room for the separate storerooms for the detail and supply department, and also permit the transfer of the polishing and plating department from Section O into Section M at the north end, next to the power-house.

Section W. The space in this section, south of the power-house, has been allotted to the instrument, experimental, model and small tool departments.

The instrument department will be located next to the offices of the production department, and will manufacture the several classes of instruments not made at the Newark Works.

Provision will probably be made in this department to test and prepare for shipment all the instruments of its own production.

The experimental department will be moved to Section W, from its present location in Section F, and its operations will be limited to experimental work only.

The model department will be used to develop the smaller types of apparatus which have passed the experimental stage and to produce manufacturing models which can be used to prepare special tools, fixtures and gauges for the economical manufacture of their constituent parts.

The small tool department will be transferred from Section F to that portion of Section W immediately south of the power-house. It will comprise the tool supply and tool repair departments, and will control, as heretofore, all the sub-tool rooms located in other departments.

In that portion of Section W enclosed by the power-house main partition walls, will be located the japanning department and the extension to the dipping and drying department, including the new vacuum impregnating and drying tanks.

Section W, north of the power-house, already contains the tool and die department, in which are made all the special tools, jigs, dies, fixtures, formers, etc., required by the various departments of the East Pittsburg works. This department will also repair the dies used by Section C, and repair many of the machine tools which become worn in other departments.

The removal of the small tool, tool, experimental and vehicle motor departments from Section F will provide for large extensions to the brush holder, commutator and screw departments, and permit the establishment of a controller department, it being the plan to utilize Section F for these four departments only.

Mezzanine Floors. Between Sections P and W and Sections S and T, mezzanine floors have been erected, upon which will be located the coat and toilet rooms for employes of the East Shop.

Casting Storehouse. Immediately north of the East Shop and connected with it is the casting storehouse extension. The casting storehouse with the extension is approximately 600 feet by 210 feet, and is divided throughout its length into three bays each 70 feet wide. The length of this building is at right angles to the length of the Main and East Shops.

The casting storehouse will contain the returned material department and scrap department for the various scrap materials, except brass and copper alloys. The major portion of its area will be utilized for the storage of castings and steel bars of the different qualities required in manufacturing operations. The storage and shipment of street railway motors will also be provided for in this building.

Transportation of Materials. One of the great problems in connection with the operation of the East Shop has been the method of transporting materials in to and out of its different departments. Two standard gauge tracks cross Sections P, R and S, and will be used for the shipment of completed apparatus from the transformer department and Section R. A standard gauge track enters the north end of Section B for a distance of 160 feet, which will be used for receiving the larger castings and forgings which enter into the product of this section.

Plans have been prepared for a complete system of industrial railway tracks connecting all the principal buildings, the main lines passing through Sections A, C, P and S, and the casting storehouse, with frequent connecting cross tracks. Later the system may be extended through the gallery floors.

The principal means of material transportation between Sections C and S will be by a tunnel passing under both the East and Main Shops. The tunnel will be provided with two industrial railway tracks, and an elevator at each end will carry loaded trucks down and up. No openings into this tunnel are made except at the termini in Sections C and S.

Twenty electric traveling cranes will be installed in the East Shop for handling the work in departments requiring their use.

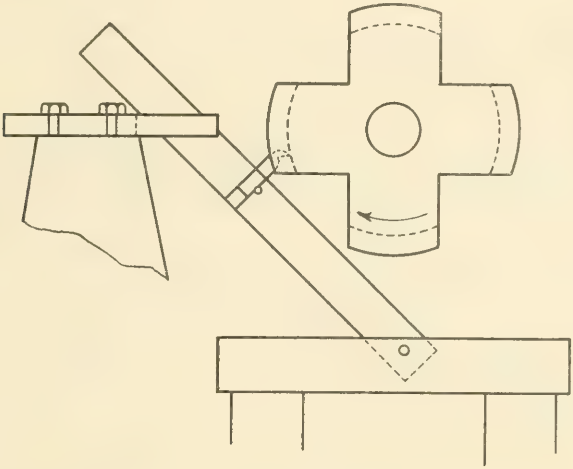
The above arrangement of departments was decided upon after careful study and now seems the best of many proposed plans. However, as departments are organized and put in operation it is not unlikely that some modification may be found advantageous.

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

Conducted by M. H. Bickelhaupt

Machine Work on Turbo-Generator Field Castings—As one operation in the construction of a large turbo-generator rotating field, the steel casting was cut through at the middle perpendicular to the shaft. As the casting was nearly six feet in diameter, a special cutting tool was rigged up to do the work. The casting was mounted on a mandrel and the work done in a lathe.



The cutting tool was firmly keyed to a steel bar ½″ thick. One end of this bar was pivoted to the carriage on the lathe-bed, while the other rested upon the upper edge of the tool-post and was raised by driving a bar across the top of the post against it. From the sketch it will be seen that the cutting edge of the tool may be made to constantly approach the axis of the piece as the work progresses, and will move in a circular arc. The lathe rotated the casting in the opposite direction to the usual one, so as to prevent the steel chips from interfering with the operation of the tool.

In making the longitudinal slots in the sides of the poles to hold the windings, a planer is used for sizes up to 1000 kw. On the large sizes a milling cutter is employed, as about twenty per-cent of the time required to plane them is saved by its use.

Action of Equalizer Rings—In large sizes of direct-current generators and rotary converters, which of necessity have parallel wound armatures, a method is employed to maintain the same potential at all the commutator brushes having the same polarity. Should the magnetic strength of field poles differ, the potential generated in the conductors under one pole would be unequal to that generated in conductors similarly located under another pole of the same polarity. This slight difference of potential would cause current to flow from one brush to another and through sections of the winding, producing excessive heating of the conductors, as well as sparking at the brushes. To obviate this difficulty, several points of the armature winding, which are normally at the same potential, are connected together, thus allowing currents to pass from one section of the winding to other sections with which it is connected in parallel. The manner in which the effect of unequal magnetic pole-strengths is corrected, by the local circuits thus formed, is as follows:

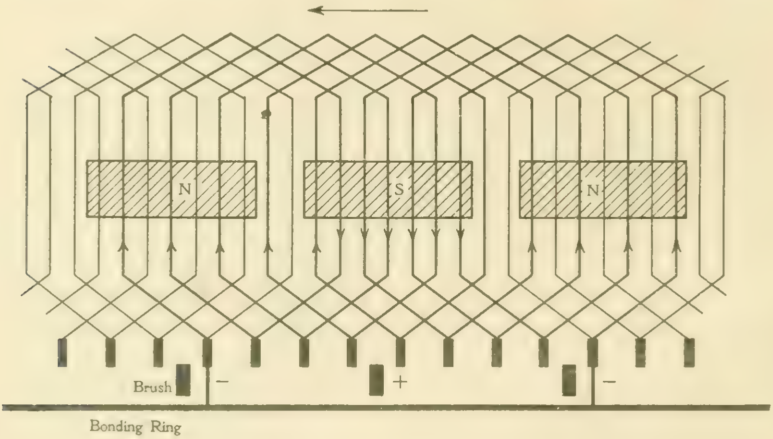


Fig. 1

Take, for example, the case of a six-pole direct-current generator having forty-eight armature conductors. Fig. 1 shows the local circuit formed by the bonding or equalizer ring and a part of the armature winding. It is seen that there are sixteen conductors forming this local circuit, and that the e.m.f's, set up in eight of the conductors oppose the e.m.f.'s set up in the other eight. When the three magnetic fields are equal in strength these two opposing e.m.f.'s are equal, and no current will flow in the local circuit; however, should the magnetic field of the left-hand N pole be stronger than that of the other N pole shown, six of the eight conductors of one set and only two of the other will be in this stronger magnetic field, as shown in Fig. 2, where the conductors in one set are distinguished from those in the other, and a current will flow in the local circuit in the direction of the greater e.m.f.

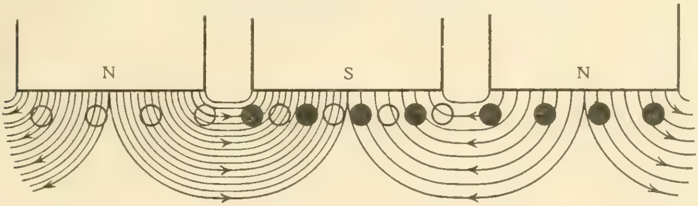


FIG. 2

The effect of this local current upon the magnetic fields is shown in Fig. 3. This action may be shown by a vector-diagram, since, so far as this local circuit is concerned, the current and, other quantities are alternating. E_1 and E_2 are the opposing e.m.f.'s with the resultant E acting in the direction of the larger, and setting up the current, I, which is lagging 90° behind E on account of the local circuit's high inductance. This current will set up the magnetic flux, M, in phase with it. M_1 and M_2 are the two main fields discussed above, which generate the e.m.f.'s E_1 and E_2 respectively, and lead them by 90°. Thus the magnetic field M is in phase with M_2, the weaker field, and directly opposed to the stronger field M_1, thus tending to equalize them.

It is to be understood that this action, as described, does not take place continuously in certain conductors of the winding. Suppose one pole of the generator is out of position so that the field under that pole is stronger than the field under the remaining poles of the machine. Then, as parts of the armature winding come under this stronger pole, there will be the local current in the winding, this current lasting only while the conductors are under the strong pole. As these conductors pass beyond the pole, other conductors take their place, in which the local current flows. While the local correcting currents flow in each conductor for only an instant, the current is always present under the stronger pole.

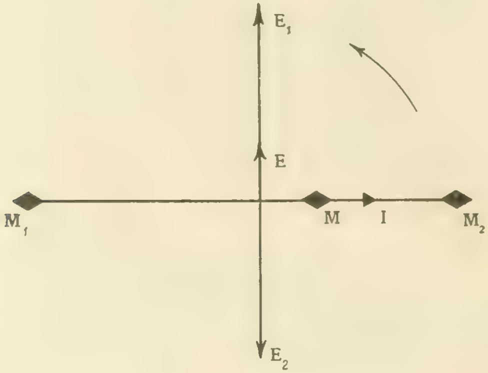


Fig. 3

WATERGLASS INSULATION—When a short circuit occurs between two bars in a commutator at or near its outer surface, the conducting material connecting the bars is generally removed by means of a sharp tool. Since this will disturb more or less of the mica, a small crevice will be formed between the segments. This crevice is filled with a liquid called waterglass, which solidifies and provides a good bearing surface, besides acting as an excellent insulation.

If a short-circuit is found to be inside the commutator and under the mica V ring, the commutator is tightly bound with rope or tape, and the proper section of the V ring taken out, when the short-circuiting material may be easily removed.

EDITORIAL COMMENT

THE PURPOSE OF THE ELECTRIC CLUB JOURNAL

That the engineering apprenticeship course of the Westinghouse Electric and Manufacturing Company is an immense educational institution is realized by few, even of those who are in every-day association with it. The apprenticeship system is so intimately connected with the purely commercial work of the factory, and is so overshadowed by it, that we do not commonly distinguish between them. But what university or technical school has two hundred graduate students studying electrical engineering? Where are there better laboratory facilities than in the various manufacturing and testing departments of the works? And where is there a finer engineering faculty than in the commercial and engineering offices of the company? For through the lecture and section work of The Electric Club, the officers and engineers of the company have truly become a faculty for the apprentice. It is true each one devotes only a very small part of his time to instruction; but, from their number, a little from each man is large in the aggregate. And the engineering apprentice is a graduate student; he knows what he wants and has the ability and the opportunity to get it; the amount of direction and inspiration he requires is adequately furnished by the work of The Electric Club. We are well within the truth when we say that the engineering apprenticeship course, supplemented by The Electric Club, is doing more for the advancement of electrical engineering education in this country than any single university or technical school.

The Electric Club Journal takes a definite place in this educational scheme. It is a logical development of the work of The Electric Club, a development that was foreseen two years ago when the Club was formed. It will put in permanent form the best work of the Club; it will increase the efficiency of the work by making unnecessary the repetition, year after year, of certain parts of its technical work; it will enlarge the work of the Club by bringing material to it that would not otherwise be available. The field of The Electric Club Journal is therefore well defined. It will be published for the members of The Electric Club, with their education and experience in mind.

The JOURNAL is not a shot-gun that is expected to hit everybody from the capitalist down to the station-attendant; but, rather, a rifle that is aimed straight at the young engineer.

We have extended the privilege of subscribing to the JOURNAL to those not members of THE ELECTRIC CLUB for two reasons: primarily, because the comparatively small membership of the CLUB could not support the kind of journal we desire to publish; and secondly, on broader grounds, we wish to extend, so far as possible, the educational benefits of the apprenticeship course and THE ELECTRIC CLUB to young engineers without these advantages.

Many things which interest younger engineers will interest older men as well—particularly in an industry which is continually advancing and in which new inventions and developments are constantly appearing.

THE ELECTRIC CLUB is composed of Westinghouse men and the papers read before it are largely by Westinghouse men; it follows that a majority of the articles printed by THE ELECTRIC JOURNAL will be written about Westinghouse methods and apparatus, by men who are responsible for Westinghouse practice. These articles, written for young men from a strictly engineering standpoint, will be all the more valuable because they are definite and relate to specific apparatus and methods, and are not abstract and indefinite. The better knowledge which may be disseminated regarding Westinghouse men and methods will be appreciated by many who are not now familiar with them. The advantage which the Electric Company will derive incidentally from the publicity given to its engineering practice will not lessen the value to the engineering public of the material we print.

Our purpose is definite: to publish a journal for young engineers, containing material suited to their needs and written in a form to meet their education and experience. To what extent we accomplish this purpose, the JOURNAL itself will determine.—*The Publication Committee.*

DRYING OUT TRANSFORMERS

THE use of insufficiently dried insulating material and the failure to dry out apparatus which has become damp are probably responsible for a great majority of the failures which have occurred with high-voltage apparatus. But trouble from this cause is not confined to high-tension apparatus alone, but appears in all classes of electrical machinery. The severe insulation tests applied to high-voltage apparatus have served, however, to emphasize the dangers of moisture, and the improvements required in the treatment of the insulation of high-voltage apparatus has resulted in a marked improvement in the quality of the insulation of all other apparatus.

With each increase in voltage, new difficulties develop. Materials and methods of manufacture which are entirely satisfactory for one voltage, may prove quite inadequate for a higher one. The inspection and care, which may be ample in the operation of apparatus at one voltage, may be wholly insufficient for a higher voltage. So called "dry wood," for example, which at 5,000 volts gives excellent results as an insulator, proves to be quite "wet" and a good conductor at 30,000 volts. To-day wood is not used as a high-voltage insulator unless first dried in a vacuum oven, then boiled in oil or otherwise treated to prevent the re-entrance of moisture. This method of treating wood is applied in a general way to almost all insulating materials, and a plant for manufacturing high-voltage apparatus is not complete without drying ovens, vacuum ovens, dripping tanks and vacuum impregnating tanks.

By these improved methods of treatment the moisture danger is largely eliminated during the period of manufacture and factory test, and to prevent the apparatus from taking up moisture during transit it is usually shipped in a hermetically-sealed case. Instances may arise, however, when the apparatus cannot be so shipped, or the case may be damaged, or during installation the apparatus may become wet, thus necessitating drying out before it is put in operation.

On high voltages the necessity for perfectly dry insulation is even more imperative than on low voltages, and as transformers are usually wound for a much higher voltage than other electrical apparatus, drying out is more frequently required on them than on other apparatus. In the next issue of THE JOURNAL will be found some general instructions for drying out transformers before they are put in service.

One of the chief difficulties in the installation of transformers is to know whether drying out is required; also when the drying out is completed. An inspection of the transformer when it is received, and a knowledge of the manner in which it has been handled during installation, may often make it clear that drying out is necessary, but when there is any doubt as to its condition, drying should be done. The insulation resistance should be taken at frequent intervals as the drying progresses, and the values plotted in a curve, for this is the only way of judging of the condition of the insulation.

In general, it is well to be on the safe side—drying out whenever there is doubt as to the condition of the apparatus, and continuing the drying out process until it is certain that the insulation is thoroughly dry.

J. S. Peck.

CLUB NEWS

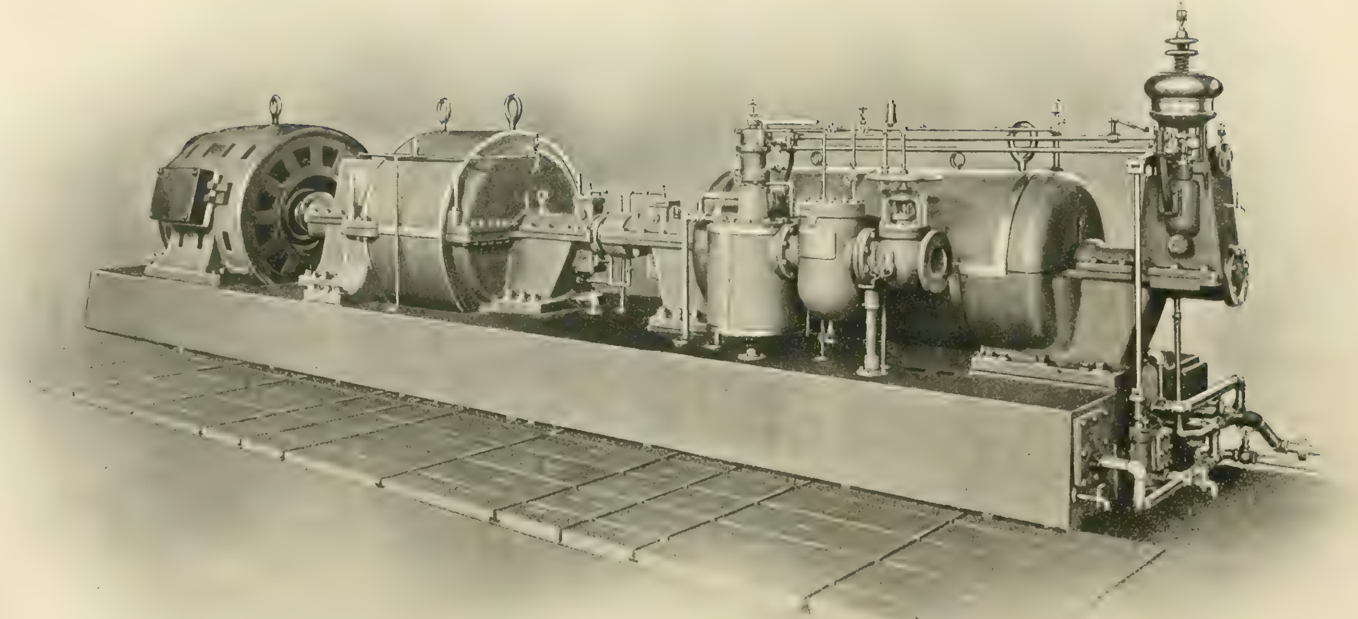
A RECORD OF THE WORK OF THE ELECTRIC CLUB

CLUB EXCURSIONS—The Excursion Committee has completed arrangements with a number of power and industrial plants in and around Pittsburg so that members of the Club can obtain the necessary passes to visit these plants.

Members wishing to visit a certain plant should organize a party of about ten men and then write to Mr. H. L. Stephenson, Chairman of the Committee, stating the plant and date for which the pass is desired and the exact number in the party. Passes for single members cannot be issued, as that would require too many requests for passes from the same company.

In furnishing these passes the Committee asks in return that each party make a written report of its trip. This report should be made by the member who obtains the pass. It should be written in such a way that members intending to visit the same plant at a later date may obtain information that would enable them to see the plant to the best advantage. To this end the report should contain specific directions for reaching the plant—assuming that the party starts from Wilkinsburg—with the time and expense required for the trip. It should tell how to get into the plant, the length of time required to go through the plant, and the best things to see. These reports will be on file in the office of the Secretary of the Club, where members may see them.

CONTINUED ON PAGE 58]



1 000 KW STEAM TURBINE WITH GENERATOR

THE
ELECTRIC CLUB JOURNAL

Vol. I. MARCH, 1904. No. 2.

THE VOLTAGE REGULATION OF ROTARY CONVERTERS

By P. M. LINCOLN

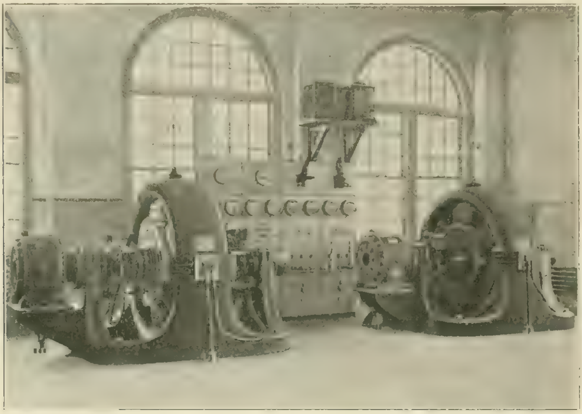
The regulation of a rotary converter differs from that of a direct-current generator in one essential: the actual increase in the voltage delivered by a rotary converter as the load increases depends not only upon its design, but also upon the characteristics of other parts of the system to which it may be connected; the compounding of a direct-current generator, however, depends entirely upon the design of the machine itself.

The external element upon which the actual compounding of a converter depends is the inductance of the supply circuit. To analyze the influence of inductance in the compounding of a converter, it is necessary first to consider what happens if a converter be operated with a varying field current while a constant voltage is applied to the collector rings.

It is a well-known fact that there is a certain adjustment of rotary converter field strength that gives a minimum alternating-current input for a given direct-current output, and that varying the field strength either way will increase this alternating-current input, while the direct-current output remains the same. In every case the alternating-current input may be considered as being made up of two components: one, the energy component in phase with the impressed electromotive force; the other, a wattless component, leading when the field strength is too great and lagging when the field strength is too small.

A constant alternating-current voltage across the collector rings has been assumed, and it is evident that the constancy of this applied voltage means the generation of practically a constant voltage by the rotation of the rotary converter armature. To generate this constant voltage in the converter armature (which runs at a definite speed) there must be a constant magnetic induction through the armature, and therefore a constant number of ampere-turns to produce that induction.

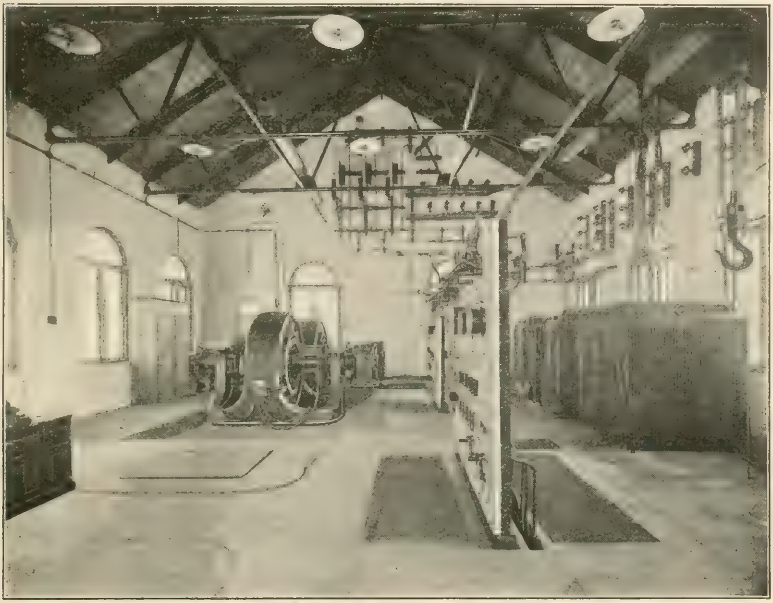
In a rotary converter, or other synchronous machine, there are two sources of excitation: current in the field winding and current in the armature winding. To produce a constant voltage the sum of these two excitations must be a constant. If the ampere-turns in the field winding are less than necessary, a current circulates in the armature in such a manner as to assist the field in magnetizing the armature. Such a magnetizing current, though leading with respect to the electromotive force of the converter regarded as a generator of electromotive force, is lagging with respect to the generator or supply system. On the other hand, if the ampere-turns of the field winding are more than sufficient to produce the constant voltage we have assumed, a current circulates in the armature in such a manner as to oppose the field winding and so reduce the magnetic induction to the required amount. This magnetizing current is leading with respect to the generator or supply system.



TWO 300 KW THREE-PHASE ROTARY CONVERTERS
Substation Berkshire Street Railway Co., Pittsfield, Mass.

The actual current circulating in the armature may be regarded as being composed of the magnetizing current and the useful current, and the ratio of this useful component to the resultant of the useful and magnetizing components is known as the power-factor of the circuit. It is measured by the ratio of the true input (recorded by a wattmeter) to the apparent input (recorded by an ammeter and voltmeter).

From the above analysis it is evident that the power-factor of the alternating current taken by a rotary converter is intimately dependent on the amount of its armature magnetizing or demagnetizing current, and therefore dependent upon the field current of the converter. The limits of variation of power-factor are from a very low power-factor lagging to a very low power-factor leading. The first occurs with a small load or no load when the field excitation is too low, and the second with a small load or no load when the field excitation is too high.



ROTARY CONVERTER SUBSTATION, SHOWING HIGH TENSION TRANSFORMERS, SWITCHBOARD AND ROTARY CONVERTERS
Utica Railway Syndicate, Utica, N. Y.

From this it will be seen that variations in field strength give lagging or leading current. It does not, however, affect the armature magnetization, and so a change in field strength alone cannot affect the direct-current voltage. This bears a fixed relation to the alternating-current voltage, so that the only way to raise the direct-current voltage is by raising the alternating-current voltage at the collector rings. Now the voltage at the collector rings of a converter is the resultant of two components; first, the voltage of the generator, and second, the voltage needed to force the current taken by the converter through the inductance between itself and the generator. The resistance between the generator and the converter is also a modifying element, but we will assume this resistance to be negligible, and without attempting at this point to give reasons, state the facts concerning the resultant of the two components.

(1) As long as the current supplied to the converter is neither lagging nor leading, the inductance volts combine with the generator volts in such a manner that their resultant, the converter voltage is practically the same as the generator voltage; that is, a non-inductive load causes practically no drop over that due to the resistance of the line.

(2) If the converter current is lagging the two elements combine in such a way that their resultant is smaller than the generator volts; that is, the electromotive force of self-induction causes an increased drop over that due to line resistance.

(3) If the current is leading, the result is greater than the generator volts; that is the electromotive force of self-induction in this case adds to the generator volts.

It is evident therefore that if we can cause the current taken by the rotary converter to change from lagging at no load to leading at full load, the voltage applied to the converter will change from an amount less than the generator voltage at no load to an amount greater than the generator voltage at full load, and it is exactly the function of the series field. It makes the field ampere-turns increase with load, and therefore as set forth above, causes the lagging component of the current supplied to the rotary converter to decrease and the leading component to increase, or both.

Now to explain the reasons why the resultant of the two components which make up the converter voltage increase as the current changes from lagging to leading. The volts across an inductance (the e.m.f. of self-induction) lag 90 degrees behind the current causing them, the resistance being negligible. This lag remains fixed under all conditions. If therefore a rotary converter current is neither lagging nor leading, the inductive volts caused by that current lag 90 degrees behind the generator volts. This condition is shown on Fig. 1, where it is evident that the rotary converter volts are practically of the same value as the generator volts. Now if the rotary converter current lags, the inductance volts are thrown around into such a position that the resultant of them and the generator volts is smaller than the generator volts.

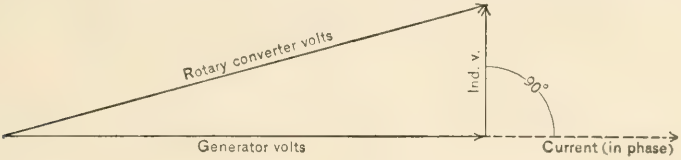


FIG. 1

This condition is shown in Fig. 2. If, on the other hand, the rotary converter current is leading, the resultant of the two elements is greater than the generator volts as shown in Fig. 3.

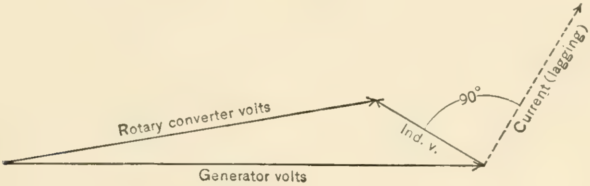


FIG. 2

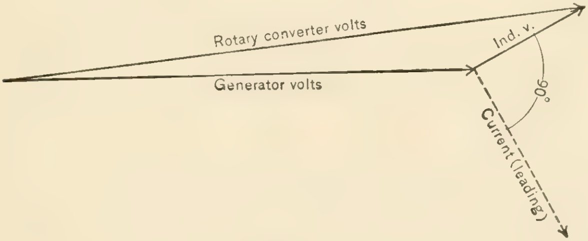


FIG. 3

It will be noted that the amount of compounding depends upon two things:

(1) The variation from lagging to leading current between no load and full load, or, referring to the diagrams, upon the change in angle between the generator volts and inductance volts.

(2) Upon the drop across the inductance, or referring to the diagrams, upon the length of the line representing inductance volts, compared to the length of the line representing generator volts.

The first condition depends upon the relative amount of series winding on the rotary converter, and this is covered by the design of the machine. The second, the inductance in circuit, depends, however, upon conditions entirely outside of the rotary converter.

In a rotary converter there are usually three sources of inductive drop, the step-up transformers, the line, and the step-down transformers. In specific cases, however, any or all of these sources may be absent. For instance, where a rotary converter is operated directly from generators in the same building, there will be practically no inductance between the rotary converter and the generator. In order to obtain compounding in this case, it is necessary to insert inductance, usually choke coils, between the rotary converter and the generator.

The preceding discussion may be briefly recapitulated as follows:

(1) A series coil on a rotary converter has the effect of automatically changing the ampere-turns applied to the field.

(2) Varying the field ampere-turns means varying the magnetizing element of the alternating current delivered to the collector rings, causing the current to become leading when the ampere turns are more than normal and lagging when the ampere turns are less than normal.

(3) The voltage across any inductance in circuit tends to subtract from the generator voltage when the converter current lags and tends to add to the generator voltage when the converter current leads.

(4) The conditions for rotary converter compounding are therefore:

(a) A series winding on the rotary converter connected so as to assist the shunt.

(b) Inductance between the generator and rotary converter.

The series field coils in a rotary converter do not increase the voltage directly, as in a direct-current generator, but indirectly, through co-operation with inductance in the supply circuit.

METHODS OF DRYING OUT HIGH-TENSION TRANSFORMERS

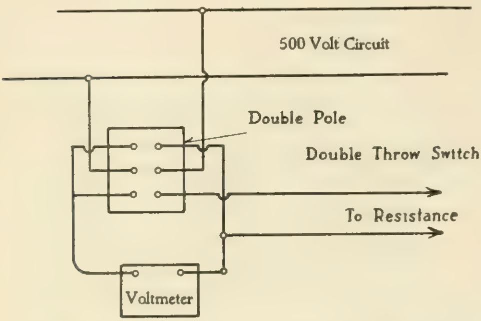
By J. S. PECK

In the manufacture of high tension transformers extreme precautions are taken to remove moisture from coils and insulation, but there is a possibility that during shipment or installation the transformer may absorb moisture. To prevent this absorption of moisture during the transit it is customary to ship the transformer in a tin-lined case. A transformer thus packed should not be opened until it has stood a sufficient time to assume the temperature of the surrounding air. If the air shows wide fluctuations in temperature the case should be opened during the cooler part of the day, for if opened while the transformer is cooler than the air, moisture will condense upon the transformer windings. The tin lining should not be opened until the transformer is ready to be placed in its case and covered with oil, or until it is ready to be dried out.

When the transformer is received the question of the advisability of drying out is one which naturally arises. If the tin lining is in good condition and there are no evidences of moisture inside this lining, such as rust upon the laminations or upon the inside of the case, drying out is generally unnecessary. But if the case is not tin lined, or the lining is broken, or there are any evidences of moisture, the transformer must be dried out before being put into service.

There is no way of telling definitely when the insulation of a transformer is perfectly dry, but a measurement of the insulation resistance will serve as an indication of its condition. The higher the resistance the dryer is the transformer. This insulation resistance is usually much lower when the transformer is hot than when it is cold, and the measurement should be made at approximately the normal operating temperature of the transformer.

In making the insulation resistance measurement a 500-volt direct current circuit and a 500 direct current voltmeter may be used. The method of making a measurement is to read first the voltage of the line, then to connect the resistance to be measured in series with the voltmeter, and take a second reading. The measured resistance is given by the following formula and the method of connecting the apparatus is shown in the sketch below.



CONNECTIONS FOR MEASURING INSULATION RESISTANCE

$$r = \frac{R\,(V-v)}{v}$$

V=Voltage of line.

v=Voltage reading with insulation in series with voltmeter.

R=Resistance of voltmeter.

r=Resistance of insulation.

In making insulation resistance measurements, great care must be taken to thoroughly insulate the conductors leading to the apparatus, otherwise the insulation resistance of the leads, instead of that of the apparatus, will be measured. On a grounded circuit the voltmeter should be placed between the line and the apparatus, and in general it may be stated that the voltmeter must be so located that the only current which passes through the insulation to be measured will pass through the voltmeter.

Instructions for Drying Out Transformers—There are three methods which may be followed in drying out transformers:

(*a*)—By internal heat.
(*b*)—By external heat.
(*c*)—By internal and external heat.

(*a*)—By internal heat. Alternating current required.

The transformer should be placed, if possible, in its case, though this is not essential, as it may be left in its shipping case or even placed on the floor of a dry room. If dried out in a case the cover should be removed to give free circulation of air. The low-tension winding should be short-circuited, and a sufficient voltage impressed on the high-tension winding to circulate the desired current through the coils. For large transformers (250 to 500 k. w.), approximately one-fifth normal full-load current will be sufficient to raise and maintain the coils at the desired temperature, viz., approximately 90°C. (194°F). For small transformers a somewhat larger current will be required.

For circulating this current through the windings, from 1% to 2% of the normal high-tension voltage at normal frequency will be required, thus for a 10,000-volt transformer from 100 to 200 volts is necessary. For controlling the current a rheostat may be placed in series with the high-tension winding.

(*b*)—By external heat.

The transformer should be placed in a wooden box, the packing case answering the purpose very well. An opening should be made near the bottom and another at the top of the box to permit a circulation of air and also to serve as a means of controlling the temperature of the air inside the box. The heat may be applied by circulating current through resistances, the iron grid form is frequently most suitable, placed at the bottom of the box. It should be applied at such a rate that the transformer coils will be maintained at approximately 90°C. (194°F). Care should be taken to protect the transformer from direct radiation from the heaters. Care must also be taken to see that there is no inflammable material near the heaters which may catch fire. This method of drying out has an advantage over the method outlined in (*a*) in that direct current may be used for heating.

Instead of placing the heater inside the box containing the transformer, it may be placed outside and the heat carried into the box through a suitable pipe. Where this plan is used the heat may be generated by the direct combustion of gas, coal or wood, *but none of the products of combustion should be allowed to enter the box containing the transformer.* Heating by direct combustion is not advised except in case where electric current is not available.

(*c*)—Internal and external heat.

The transformer should be placed in a wooden box as in (*b*) and external heat applied, while at the same time a small amount of current is circulated through the transformer windings. The method of circulating the current should be the same as given in (*a*) and the method of applying the external heat the same as given in (*b*). The current should, of course, be considerably less than when no external heat is used, the value being determined, to a certain extent, by the amount of external heat applied. This method is used occasionally where direct current only is available, a certain amount of current being passed through the high-tension winding only, as the low-tension winding is ordinarily wound for so heavy a current that it cannot be obtained economically from a direct-current circuit.

The length of time the drying-out should be continued will depend largely upon the condition in which the transformer is received, and unless in very bad shape, a week's run should be sufficient to put the transformer in good condition. In certain cases, however, it has been found necessary to continue the run for a somewhat longer time.

It will be found that when the current is first applied and the transformer heats up the insulation resistance will drop very rapidly, until the desired temperature is reached; then, as this temperature is maintained constant, the resistance will gradually increase. It will also be found that variations from a constant temperature will cause wide changes in resistance. Resistance readings should be made every few hours and the drying continued until the resistance no longer increases, or increases at a very slow rate.

Precautions to be Observed—In order to dry out the transformer, it is necessary to maintain it at a temperature which approaches the point where fibrous materials deteriorate. Great care must, therefore, be observed during the whole period of drying out to see that the temperature does not reach a value much in excess of 90°C.

For measuring the temperature of the transformer coils, several thermometers should be used. These should be placed well in between the coils, near the top of the transformer, and screened from air currents, so that they will indicate the maximum temperature of the windings. As the temperature will rise quite rapidly at first, it is necessary to watch the thermometers carefully to see that the maximum allowable temperature is not exceeded.

As the transformer is soaked with oil, on account of the test which it receives in the works, the material is in an inflammable condition, and while hot it may be ignited very easily by a very small arc or from a blaze of any kind. Before beginning the drying out, it is well to have some chemical extinguisher, or at least a supply of sand, at hand, which may be used in case of necessity. *In general, it is not safe to attempt the drying out of transformers unless constant attention can be given to them.*

GAS POWER-PLANTS

A Lecture Delivered Before The Electric Club, November, 1903

By A. M. GOW

The supremacy which the steam engine has held for so many years as a prime mover is at present being contested by the steam turbine and the gas engine. Like the steam engine, the steam turbine requires, as an adjunct, a steam boiler. Each converts into work a portion of the heat generated by the combustion of fuel in the boiler furnaces. The gas engine differs fundamentally from these two forms of prime movers, in that the combustion and consequent generation of heat takes place immediately in the cylinder in which a portion of that heat is converted into work. The remarkable economy of fuel, which is readily attained by gas engines, insures their extensive use in larger and larger sizes, and their general adoption as sources of power in central stations within the comparatively near future. In many places water economy is as important a feature of a power-plant as fuel economy, and here the gas engine has a decided advantage over the steam engine or the steam turbine. Furthermore, the dispensing with steam boilers under high pressure, with the usual danger and heavy cost of maintenance, is an advantage that will be much appreciated by power-users. The gas engine, as a machine, is as reliable as the steam engine. The engine and the accompanying gas-producing plant require no more skill nor higher-class labor for their operation than do a battery of boilers and a steam engine. In fact, in those cases where the user of power gets his gas from gas mains, and does not manufacture it himself, the labor item is greatly reduced. Economy of space is also effected by the use of gas engines, for while the gas engine is a larger machine for a given horse power than the steam engine, this is more than offset by dispensing with the steam boiler.

In short, the gas engine stands for economy—economy in fuel, water, labor, space and maintenance. As to first cost of installation, in most cases, there, too, the gas engine has the advantage; but even where the first cost is much higher for the gas engine installation, the power-user may depend upon it that the economies effected will pay big interest on the increased investment. Getting rid of steam boilers effects a saving on the wear and tear of the nervous system, incident to the maintenance of a "magazine of explosive energy;" but it is rather difficult to make even an approximate financial estimate of this item of economy.

The problem which confronts the engineer who contemplates the installation of a gas power-plant is not to obtain a satisfactory engine but to obtain a satisfactory gas. A gas engine will operate successfully upon almost any mixture of gases containing from 100 to 1,000 British thermal units to the cubic foot. The only essential is that the gas should be clean—that is, free from dust or condensible vapors, which will make trouble with the igniters, valves and packing rings. A gas which is piped for general distribution for illuminating or heating purposes is always clean enough for gas engine use; and such gas is admirably adapted for use in gas engines. But except in those places where bounteous Nature has been lavish in her supply of natural gas, such gas is too high in cost to warrant its use for any but small installations. Natural gas is an ideal fuel for use in gas engines, and it is not probable that any artificial gas will ever be manufactured possessing all the desirable characteristics of the natural product. Twenty years ago natural gas in the Pittsburg district was nearly as cheap as air, and the mistaken idea that the supply was inexhaustible, together with crude methods of distribution and use, led to its most extravagant waste. At that time the gas engine had not been developed in large sizes. Now that the gas engine has been developed the supply of gas has seriously diminished, with a corresponding increase of price, and promise of further increase in the future. The field, therefore, for the use of gas engines with natural gas is a limited one, and one which in all probability will narrow rather than broaden.

The ordinary illuminating gas, distributed in all cities, is all that can be desired as fuel for a gas engine, but its high price makes it out of the question for large, central power-plants. For comparatively small installations it is already in great favor, and is coming more and more into use. In many cases the economies above recited, incident to the use of gas engines, more than offset the increased cost of illuminating gas over the cost of coal fired under a boiler.

Illuminating gas is derived from coal by two processes, both of which are in general use. In the older and original process, bituminous coal is charged into retorts set in a "bench." These retorts are maintained at a red heat by the combustion of fuel in a furnace located near the bottom of the "bench." The volatile matter of the coal, consisting of gases and vapors, is distilled from the coal in the retorts and passes through suitable scrubbers and purifiers, whereby the condensible vapors and the impurities, such as ammonia and sulphur compounds, are removed. It is then suitable for distribution as illuminating gas. The non-volatile portion of the coal is removed from the retorts as coke, and the retorts charged again with a fresh charge of coal. This, in general, is the process of making "bench" or distilled gas. The other process converts the coke left from the "bench" gas process into gas. This is known as the "water gas process." It depends for its operation upon the fact that when incandescent carbon is brought into intimate contact with steam, the steam is decomposed into oxygen and hydrogen ; the oxygen combining with the carbon to form carbonic acid gas and carbonic oxide gas, while the hydrogen remains as free hydrogen. Inasmuch as carbonic acid is incombustible, while carbonic oxide is combustible, the apparatus should be operated in such a manner as will produce as large a percentage of carbonic oxide and as small a percentage of carbonic acid as possible. To accomplish this result the two requirements are skill and temperature. The resulting "water gas," composed of hydrogen, carbonic oxide and carbonic acid, burns with a blue flame, and is not suitable for distribution as an illuminating gas. Consequently there is added to it a percentage of gas derived from oil which burns with an intensely luminous flame. The final mixture of water gas and oil gas is known as "carburetted water gas." Straight water gas, without the addition of oil gas, is not well adapted for use in gas engines. The large percentage of hydrogen which it contains makes it very "snappy," and, as a result, it becomes difficult to control the exact time of ignition in the engine cylinder. The presence of the oil gas, while increasing the total heat content, retards the combustion ; that is to say, the rapidity of combustion of water gas is much greater than that of oil gas ; consequently the rapidity of combustion of water gas is retarded by the admixture of the oil gas.

In this connection it might be well to note the relative action of steam and gas in an engine cylinder. Steam is admitted to the cylinder under boiler pressure and this pressure is maintained until the "point of cut off" is reached; then the steam expands. In the gas engine there is no "point of cut off." The explosive mixture of gas and air is compressed and then ignited. An explosion results with a consequent sudden increase of pressure. The indicator card shows no "admission line" of pressure with subsequent cut off. The card resembles a "no load" card of a steam engine. Now it is evident that if the gas in the cylinder burned slowly and its combustion, with consequent generation of heat and pressure, extended over an appreciable increment of time, the card would more resemble a steam engine card with early cut off, and the initial pressure would not be as high as if the explosion had taken place instantaneously. It is evident, therefore, that a gas which burns slowly is better adapted for gas engine use than one whose combustion is almost instantaneous—such as hydrogen. Straight water gas contains such a high percentage of hydrogen that its combustion is extremely rapid. Mix some slow burning oil gas with it and the combustion of the whole is sufficiently retarded to give excellent results in the engine cylinder. But it must not be understood from the above that it is possible to so retard the combustion of an explosive mixture of air and gas in an engine cylinder that the pressure shall remain uniform through any great part of the stroke, and the resulting card show a "line of combustion" like a "line of admission" on a steam engine card.

The gas which escapes from the top of a blast furnace during the operation of reducing iron ore to metallic iron is well adapted for use in gas engines. It is very low in calorific value, having, as a rule, not more than one-sixth the heat units contained in illuminating gas and not more than one-tenth those contained in an equal volume of natural gas. In Europe great progress has been made in the use of this gas for power purposes, and it is perfectly safe to say that the next few years will see blast furnace gas extensively used in this country for the generation of power.

All that it requires to render it suitable for use in engines is to cool it and clean it from the dust and particles of fine iron ore which it contains upon leaving the furnace. But the use of this gas demands that the engines be placed somewhere in the neighborhood of the furnace; and if it were desired to install a power-plant in the heart of New York City, it would not be practicable to install a blast furnace to produce the gas for power and have the pig iron as a by-product. Nevertheless, Pittsburg's blast furnaces may yet operate her trolley lines.

In the manufacture of coke from bituminous coal there is of course an enormous evolution of gas. In the ordinary bee-hive coke oven no attempt is made to save this gas. In the "by-products" coke oven, however, a portion of the gas is saved, and this gas is, for use in gas engines, the equivalent of bench gas. The Connellsville coke region, as a place for the generation of power, has in it all the possibilities of a Niagara.

In regions where crude oil is abundant and cheap it becomes commercially possible to make an oil gas that works well in a gas engine; but such regions are rare. Oil for fuel must be of very limited application.

Inasmuch, therefore, as natural gas, illuminating gas, blast furnace gas, coke oven gas and oil gas are of limited application for power purposes, the engineer who contemplates the installation of a large central power-plant using gas engines is usually compelled to fall back on the same fuel he would use in case he installed steam engines, namely, coal. And the problem becomes: What is the best means to produce from coal a gas suitable for gas engines? There can be but one answer to this question: make straight producer gas in a gas producer.

When air is passed through a deep body of fuel, the combustion is incomplete.

Now, complete combustion of carbon produces carbonic acid, which is an incombustible gas. Incomplete combustion produces carbonic oxide, which is a combustible gas.

This carbonic oxide may be removed from the producer in which it is formed, cooled and cleaned and used in a gas engine. Of course, the inert nitrogen of the air accompanies the carbonic oxide and serves only as a diluent. The partial combustion of the fuel generates heat and, unless something were done to keep the temperature down, the producer would get too hot and the ash would fuse to clinker. So it is customary to add steam with the air entering the fuel bed. This steam serves to prevent clinkering, and in addition, some of it is decomposed. The producer gas thus made also contains some hydrogen, derived from the volatile constituents of the coal.

It will be seen, therefore, that the process of making producer gas is an extremely simple one. The commonest form of producer is a cylindrical shell, lined with fire brick, with means for the introduction of coal at the top and air and steam at the bottom. The ashes are removed from the bottom. The fuel bed is maintained from four to six feet deep. The gas passes off from above the fuel at the top of the producer. It is customary to use steam under pressure, and by means of an injector cause the steam to entrain the necessary air. If desired, the air may be introduced by means of a fan, and steam pressure avoided. The process is a continuous one. Coal is charged as often as needed; the ash may be removed with the producer in operation and a constant quantity of gas, of uniform quality, produced. Gas made by this process from coal will vary from 120 to 150 B. T. U. per cubic foot. Consequently it is not adapted for purposes of distribution, being too low in calorific value; but it is an excellent gas for use in gas engines. Soft coal, hard coal, coke or wood may be used as fuel. Upon leaving the producer the gas is always hot and dirty. It must be cooled and cleaned before it can be used in the engine. The cooling is a comparatively simple matter, but the removal of the dirt is a more difficult one. If hard coal or coke is the fuel, the gas is comparatively clean, and by merely passing it through a static scrubber—an iron shell filled with wooden grids, over which water trickles—the fine particles of dust may be removed. But if the fuel is soft coal, the gas contains, in addition to dust, a large amount of tar and heavy, condensible vapors, derived from the volatile matter of the coal. If allowed to go to the engine, the tarry vapors will cause serious trouble. While there is one form of internal combustion engine which consumes oil directly in the cylinder, the gas engine proper, as constructed now, will not operate successfully on gas containing a heavy, tarry vapor. The tar vapors must be condensed and removed from the gas.

The devices for accomplishing this are legion, and their number is rapidly increasing. Such devices are called "scrubbers," and they are of two general types—stationary or static scrubbers and revolving scrubbers; and the revolving scrubbers are of two general types—slowly revolving or "washer scrubbers," and swiftly revolving or "centrifugal scrubbers." The only objection to the static scrubbers is their large size and the difficulty of cleaning them. They are thoroughly efficient, and in general use on a large number of comparatively small installations. But there is a strong demand for a small, self-cleaning scrubber, especially adapted for use in large power-plants. The slowly revolving "washer scrubbers," in connection with tar extractors, are extensively used for cleaning illuminating gas, which is heavily charged with tar upon leaving the retorts. But they are large, cumbersome machines, and do not fill the requirements of a scrubber for cleaning producer gas derived from soft coal for engine use. Many attempts have been made to produce a high-speed centrifugal scrubber which will remove, not only tar, but any fine dust the gas may contain. Operating on blast furnace gas, such centrifugal scrubbers have met with considerable success, but there is not in general use, at this writing, a thoroughly satisfactory centrifugal scrubber which, with the expenditure of a small amount of power, will thoroughly clean producer gas. So many attempts are being made on this line, and the experiments have met with so much success as to leave no doubt that such a device will be perfected in the very near future.

But the tar represents so large a percentage of the heat value of soft coal and is such objectionable stuff to handle that many attempts have been made to evolve a producer that will gasify the tar and produce a gas practically free from it. This is a consummation devoutly to be wished, and when it is accomplished, as it surely will be, the gas engine business will receive a wonderful impetus. All that is needed now is a gas producer which will render into a "fixed gas" the volatile constituents of soft coal. The Patent Office is a veritable grave yard wherein such devices lie buried. Very few of them will ever be resurrected.

Tar vapors can be very effectively broken up into their constituents, hydrogen and carbon, by passing them through hot coke. Therefore it has been proposed to connect a coke chamber to a producer and pass the dirty gas from the producer through the hot coke; to insure a supply of hot coke have two chambers and use them alternately, one being blown hot while the other is in use. Fairly successful results in breaking up the tar vapors have been attained by working the producer downward instead of upward, as is usual, whereby the vapors first driven off from the fresh charge of fuel are compelled to pass through the mass of partly coked fuel below. Producers have been built in pairs, with reversing valves, so arranged that the gas made in one producer would have to pass down through the other. After a suitable period of time the valves would be reversed and the operation conducted in the opposite direction. It has been proposed to withdraw the gas from the middle of a very deep fuel bed, the upper half of which is working downward and the lower half upward. These are only a few of the many schemes devised to solve this apparently simple problem. The fact remains that there is not on the market to-day a thoroughly satisfactory producer which will make clean producer gas, free from tar, from soft coal. To be "thoroughly satisfactory" such a producer should be extremely simple in mechanical construction and be capable of continuous operation; without the necessity for a shut down for removal of ash or clinker and run week in week out without being emptied. It is the lack of such an ideal producer that stands in the way to-day of the general adoption of the gas engine.

But because the ideal scrubber and the ideal producer for use with soft coal have not as yet been fully developed is no reason for hesitancy in installing gas power-plants. If hard coal is available for fuel the plant is simpler and easier of operation than a steam boiler and engine plant of the same size. Thoroughly reliable gas producers are on the market which, operated in connection with the most economical type of engine, will give a combined thermal efficiency for the entire plant of twenty per cent. That is to say, a modern gas engine and producer plant will convert into useful work one-fifth of the heat contained in the coal. Depending upon the size of the plant and the quantity of the coal, the coal consumption per horse-power hour will vary from one pound to one pound and a quarter. Now a steam plant that will deliver a horse power for two pounds of coal per hour must be of the most economical type and in the best condition. Three pounds of coal per horse-power hour is considered good work and the steam plants that attain it are exceptional ones. The gas from hard coal is very easily cleaned in static scrubbers that are inexpensive to build and require very little attention. Such plants are in use and giving entire satisfaction.

If hard coal is not available and soft coal must be used the question of scrubbing is a more serious one. The tar represents some thermal loss. The scrubbers must be large and easily cleaned. But even with these objections the plant as a whole is much more economical than a steam plant of the same size, and fully as easy to operate.

On the opposite page will be found a table giving typical

TYPICAL ANALYSES.

	H_2	CH_4	CO	C_2H_4 ILLUMINANTS.	CO_2	N_2	O_2	B.T.U CU FT	O_2 FOR COMBUSTION	AIR FOR COMBUSTION	B.T.U. IN 1 CU.FT. EXPLOSIVE MIXTURE
BENCH-GAS	46.00	40.00	6.00	5.00	50	2.00	5	646	1.21	6.05	91 7
WATER-GAS	48.00	2.00	38.00		6.00	5.50	5	295	.47	2.35	88.0
PROD'R GAS HARD COAL	20.00		25.00		5.00	49.50	.5	144	.225	1.12	68.0
PROD'R GAS; SOFT COAL	10.00	3.00	23.00	50	5.00	58.00	.5	144	.24	1.20	65.5
PRODUCER GAS; COKE	10.00		29.00		4.50	56.00	5	125	195	98	63.0
CARBURETTED WATER-GAS.	40.00	25.00	19.00	8.50	3.00	4.00	5	575	1.05	5.25	92.0
COKE OVEN GAS	50.00	36.00	6.00	4.00	1.50	2.00	.5	603	112	5.60	91.0
BLAST FURNACE GAS	1.00		27.50		11.50	60.00		91	143	.72	53.0
NATURAL GAS; PITTSBURG.	3.00	92.00		3.00		2.00		978	1.945	9.73	91 0
OIL-GAS	32.00	48.00		16.50		3.00	5	846	1.615	8.07	93.0

CONSTITUENTS OF COMMERCIAL GASES.

	CHARACTERISTICS	MOLECULAR SYMBOL.	MOLECULAR WEIGHT	B.T.U PER CU.FT	B.T.U. IN 1000 CU.FT. FROM 68°-68°F.	CU.FT. O_2 TO BURN 1 CU.FT.	PRODUCTS OF COMBUSTION.
HYDROGEN	BLUE FLAME: VERY "SNAPPY"	H_2	2	320	320,900	.5	H_2O
OXYGEN	SUPPORTER OF COMBUSTION	O_2	32				
NITROGEN	INERT	N_2	28				
CARBONIC ACID	INERT, BURNT CARBON	CO_2	44				
CARBONIC OXIDE.	VERY POISONOUS; PARTIALLY BURNT C. BLUE FLAME	CO	28	320	320,580	.5	CO_2
MARSH GAS	SLIGHTLY LUMINOUS. ODERLESS	CH_4	16	1000	993,550	2	CO_2 & $2H_2O$
OLEFIANT GAS	LUMINOUS	C_2H_4	28	1600	1,560,100	3	$2CO_2$ & $2H_2O$
ACETYLENE	VERY LUMINOUS	C_2H_2	26			2.5	$2CO_2$ & H_2O

analyses of the various gases available for use in gas engines, the oxygen and the air required for theoretical combustion and the b.t.u. contained in one cubic foot of the gas mixed with the theoretical amount of air required for its combustion. From the last column of this table it will be seen that the thermal value of the gas is by no means a measure of the number of the thermal units contained in a given volume when the gas has been mixed with the requisite quantity of air to insure its combustion. For instance; one cubic foot of a mixture of natural gas and the theoretical amount of air required for its combustion will contain 91 B. T. U. A mixture of blast furnace gas and the theoretical amount of air required for its combustion will contain 53 B. T. U. Yet a cubic foot of natural gas contains more than ten times the B. T. U. contained in a cubic foot of blast furnace gas. The reason is evident: It takes 9.73 cubic feet of air to supply the oxygen necessary to consume one cubic foot of natural gas and only .72 cubic feet for a cubic foot of blast furnace gas, the gases being of the analysis given. Furthermore, to insure complete combustion in the engine cylinder it is necessary that an excess of air, beyond the theoretical requirement be provided; and the higher the calorific value the greater the excess. In practice it is found that an engine when using gas of very low calorific value will develop seventy-five per cent of the load which can be developed when using gas of the highest calorific value. Consequently the use of low grade gas demands but a slight increase of cylinder diameter over the diameter required when using high grade gas, to develop a given horse-power.

The gas engine and the producer plant to produce gas from any grade of fuel have passed the experimental stage. They are not engineering possibilities; they are engineering achievements. The use of power, contemplating the erection of a new plant or desiring to secure economies over existing ones, should consider the installation of gas engines; and the engineer who desires to familiarize himself with the most economical means for the generation of power from fuel should keep in touch with the rapid development now being made in gas engineering.

MAN-POWER

The Major Portion of an Address Before The Electric Club, May, 1903

By T. C. FRENYEAR

What interests us to-night is not the horse-power of waterfalls and engines, but a kind of power that pertains only to living beings possessed of will, which for lack of a better name we will call Man-Power.

These are the days when the most effective power resides elsewhere than in the muscular tissues. Its presence in a man we can discover only by what he does and his manner of doing it.

The power of which we speak is not authority, though authority usually involves power and is often called power; but the vital effective quality, real power, is exercised irrespective of authority; it transcends all ordinary limitations; there is in it a compelling element, a necessity which cannot be held down. Those who seek positions of authority in order to exercise the power they crave would better look within and develop within themselves such forces and power as will, by necessity, be effective when developed, whatever the outward relations of the individual may be. How often is it to be found that the real force, the most powerful man in a community, is not the mayor, but some quiet unofficial person, the still waters of whose influence run very deep.

It does not take a great experience of life to convince us that effectiveness and success are not measured by physical strength, by intellectual acuteness, nor by opportunity. Some of the brightest minds in our college classes have failed to make any adequate impression on their times. On the other hand some of the men who have accomplished great things in the world have been simple men of moderate abilities, but have been endowed with a tremendous energy. Their lives have been devoted to the purposes chosen for themselves. In the words of Phillips Brooks, himself a masterful man and close to the divine source of power—"It does not take great men to do great things; it only takes consecrated men"; that is, devoted men, men who have yielded themselves completely to an ennobling, inspiring power greater than themselves.

If then you would accomplish something, if you would bring things to pass, if you would have the power to express your ideals in your work, if you would turn your visions into facts, the first essential is faith—belief that you can. The world has little use for the coward; it has little use for the cynic; but it has work enough to do for the man who is brave, believes in himself and is not afraid of the consequences of his own energy. Believe in the best men, believe in your best self, but believe in *something*. Mere doubters and deniers are not constituted so that they can do things; they are a negative, minus quantity; not positive, plus.

The second essential, and it is very like the first, is getting into right relations with the source of all power.

The time in which we live has been variously called the age of steam, the age of electricity, the age of machinery, the age of organization. Would it not better be called the age of POWER, that deep and broad characteristic of the time of which steam, electricity and organization and even life itself are only some of the outcroppings?

Can it be that there is more power in the world now than in previous ages? The conservation of energy is an accepted doctrine; the development of water-powers and the multiplication of steam engines, even the gas engine and the steam turbine, have not increased the energy in the world one iota. We have only drawn upon Nature's exhaustless reservoir; we have begun to harness her wild forces, but we have not added a particle to her power. When the rivers of earth run dry and its fires are out, somewhere in some form will throb the same eternal energy.

It is not quite as likely to be true that the energy of the will, of the spirit, is a constant quantity also; that the power in man no longer latent but dynamic, which has made use of the forces of nature, which has organized human society, which has produced great literatures, which has built marvelous engineering works, is not a new thing in the universe, but only a new and various manifestation of an eternal and ever constant spirit energy? Emerson, though writing before the marvelous developments of the last three decades, says, "All power is * * a sharing of the nature of the world. The mind that is parallel with the laws of nature will be in the current of events, and strong with their strength."

Possibly no man of the last century had greater influence in uplifting the lives of young men than Henry Drummond, largely because of his skillful use of the truths of science to illuminate the life of the Spirit in man. I believe that we can turn the tables; that likewise the common-places of religion may help to disclose the source and the means of exercising personal power. Whether with Spencer we acknowledge the "infinite and eternal energy from which all things proceed," or with Matthew Arnold a "power not ourselves which makes for righteousness," or with men of far different temperament, we look up with personal devotion to an infinite and loving Father, is it not altogether probable that He is the source of all personal power, no matter in what channel or for what purpose it may be exercised, that He is the limitless reservoir upon which we may draw, and that the secret of developing power ourselves lies in right relations to this infinite energy?

Man may oppose for a moment the mighty forces about him, but at his peril. To become the vehicle of power he must yield himself without reserve to the great purposes of the Infinite, and he will suddenly find vast forces co-operating with him so that even the stars in their courses are fighting for him, not against him. One of the characteristics obviously necessary in order to comply with this condition is rectitude, straightness. Our faith may be shaken at times by the apparent prosperity of the mean and crafty, but our view is too short: the universe is against them; truth and rightness can alone win what is enduring and worth while.

The third essential, if you would achieve, is work, WORK, WORK. Work is the putting forth of strength; if the power resides in one he must work. As Emerson says, "This affirmative force is in one and not in another, as one horse has the spring in him and another in the whip."

Having the first two essentials, work is the farthest removed from drudgery; it becomes play, because we are grown so that the activities of work are to us what play is to the child: we reach a consciousness of strength such that the most strenuous of work flows from our hands and brains an easy, natural, powerful stream. Work is hard only in relation to the strength of the worker: all work becomes easy to him who draws upon unlimited forces.

It is obviously necessary to draw limitations about our inquiry at this time as to the development and right use of man-power. Its manifestation in the control of men, especially through industrial organization, and the validity of this control in a democratic society, has appealed to me as of timely interest to us all.

Is not power over fellow-men a dangerous thing? Have we not struggled for two centuries and more to throw off the yoke? Are we not in America to-day free and equal, at least in part, and striving to be as to the rest? Happily we live in an age when the fetters of the slave have been broken and the lordship of the feudal baron is long past, but leadership and the power of the few over the many are quite as real and important as ever before in the world's history. Things must be done, and no more effective way has been evolved than the organization and exploiting of the labor of the many by the few who are endowed with the power to utilize them in carrying out great plans.

But obviously the democracy in which we pride ourselves, if it is to be more than a name, involves the freedom of the individual will to an extent which precludes the control of large bodies of men by the command of authority alone: no such sanction is recognized except in necessarily undemocratic organizations like the army and navy. How significant, nevertheless, that the present era of almost universal democracy is marked an expansion of social and industrial organization upon a scale of magnitude and perfection never before conceived!

A hundred years ago the units engaged in production and distribution were small, for the most part individuals, and the tendency of the century has been increasingly toward the aggregation of these units into immense organizations. The democratic movement in itself was largely industrial in its origin, a vigorous reaction against feudalism, whose worst faults were economic rather than political. Can it be that we already witness a reaction against democracy in the present trend to combination and unification of control? Are large organizations, political, social, or industrial, under the control of a single person, compatible with the fullest exercise of freedom guaranteed by a democracy?

Carlyle tells us how the word king originally signified the man of exceptional ability, the kon-ning, kan-ning man, the man that can. The name came into disrepute with us democratic moderns because by heredity or other means it fell to men who were not able, who could not maintain its traditions. In democracy there is still just as much need for the man who CAN, but he is no longer called king, and he is selected by natural, not artificial, processes. And in a democracy his methods and means of exercising power cannot degenerate without ultimately raising up in his stead a man who better CAN. We must have rulers, men of power, and they are selected, not primarily by our ballots, but by the inevitable cosmic processes of evolution.

How must executive control be exercised in order to be effective and yet not abhorrent to democracy and subversive of freedom? In other words, what is the true principle of organization in a democratic community? GETTING OTHERS TO DO WHAT YOU WANT DONE WHILE THEY ARE DOING WHAT THEY THEMSELVES WISH TO DO. Inspiring others with a desire to do what you want done, not driving them to do it. Knowing men, setting before them the objects of their ambition and affection in the line of your own purposes.

At first this may seem to be only a new form of slavery ingeniously devised to deceive its victims, but if rightly understood, it is farthest from that. Such organization develops men, brings them into effective relations, is like building a useful and beautiful house with stones and bricks, by themselves of no use and little beauty. This organizing ability is a matter of power and may be abused, it is true, for a time, but not for long: it is essentially moral; we who are made, or at least are being made, in the image of God, come nearest to His likeness in organizing and doing great things with the aid of other men whose wills we inspire, and by means of the materials and forces with which He has filled the world and which we have conquered. This is little short of creation.

But how about the many who are used by the powerful few? Is there any radical difference between past and present, despotic and democratic methods of control?

Dew and rain and glorious sunshine are necessary to the normal growth of plants beautiful and useful. The house-plants, shut-ins, are always at a disadvantage, and would not grow at all but for artificial watering and partial sunlight. Organization along undemocratic lines, control by force, or by command ignoring the wills of those controlled, constitutes a repression, a shutting-in, which stunts and dwarfs the individual life. Then the artificial waterings of philanthropy and the stained glass light of the church are necessary to save even a remnant of manhood.

But the instruments of true organization are hope, not fear; ambition, not despair; love, not indifference. The true master of men appeals to the higher motives and aspirations; creates an atmosphere which awakens and inspires; is big, bold, powerful, and attracts and attaches to himself the wills of his men. His purposes are served quite as much by those who are unconscious of any allegiance to him as by his conscious partisans or employees. He does not vainly complain of any untoward event, but is always alert to take advantage of every change and circumstance. He is a master of things as well as of men; indeed, forces, things, men, are all the raw material out of which he builds vast structures, using each according to its fitness for his plan, but without violating either the laws of matter or the individuality and freedom of man. He is great enough to know that men can be of great use to him when free to develop to the fullest extent.

He has need of many sub-leaders. The organization of to-day would be impossible on the plan of half a century ago, when it was the glory of the employer to have personal relations with each of his men. There must be district leaders, and ward leaders, and commanders of precincts. Men competent to control a district, a shop, a room, are in constant demand, and true organization tends to develop such men and put them in positions they are fitted to fill.

It has been said that great business establishments fail to develop the individual because they destroy in a large degree individual initiative. Such a statement is true only of the few organizations still maintained on a despotic basis. Even in the case of army organization, which is necessarily despotic in character, our army is said to be superior in the field to any other on account of the superiority of the individual units in zest and in power of initiative when by some fortune of war the men are left to their own resources. General rules there must be, but they are the product of a long evolution and framed by master minds. The important point is that the members of a large industrial organization, each in his individual sphere and under the general direction only of the owner or manager, are free to act as they will. In other words, each is charged with responsibility for a certain piece or kind of work, and is judged by results; and it is responsibility which develops character.

Though general rules are necessary, that man is most valuable in any position, who can, when the need comes, rise above all ordinary regulations and himself assume responsibility and initiate new plans and policies.

Elbert Hubbard in a recent *Philistine* tells of Tom Potter, the telegraph operator at a little way station, who one wild night, when wires were down and a passenger train went through the bridge, took charge of the dead, cared for the wounded, settled fifty claims —drawing on the Company therefor—burned the wreckage, sunk the waste iron in the river and repaired the bridge before the Superintendent arrived on the scene. "Who gave you authority to do all this?" demanded the Superintendent. "Nobody," said Tom, "I assumed the authority." Next month his salary was at the rate of $5000.00 a year. Men are wanted who can and dare do things.

This story of Tom Potter, unquestionably true in its moral, I had doubted as a statement of actual fact until some weeks ago I met a railroad man from the west, who told me he knew Potter very well and who verified the story substantially as told by Hubbard.

Railroads are probably the best organized because oldest of our great industrial corporations, and, while rigid rules are necessary in controlling a business covering so vast an area, each head of department, division superintendent, track master, station agent, and train conductor is free and supreme in his sphere.

The most conspicuous examples, however, of true industrial organization are the great trusts and manufacturing corporations, whose existence would be quite impossible without the practice of those higher methods of democratic control which we have been considering. The most potent individual factor in the industrial life of this country is doubtless Mr. J. Pierpont Morgan, who is not even a director in some of the corporations he controls and in nearly all of them some other than he is the titled head. Yet the form and activities of many large railroad and manufacturing companies to-day are what he has thought and made them. He has won his place of unexampled power by using other men on a tremendous scale, by being stronger than they and impressing his views and ideas upon them, by such mental vitality that he has been able to inspire multitudes of lesser men with such portions of his vast ideals as he wished them to create. Are they his servants? Yes, they help to carry out his plans, but it is not unwillingly or by any compulsion that they do his bidding. They are greater men, more truly free, because of their association with and allegiance to him. To use an illustration from the literature of religion, Paul of Tarsus, whose influence in shaping modern civilization has been of the first order, rejoiced to call himself the bond-servant of Jesus Christ, and yet he went about the work of a servant in a most masterful way, with unbounded energy and enthusiasm.

Of one of the greatest captains of industry I hesitate to speak here, where there is so much to remind us of his interest in the young men who are to carry on some of his work. He is in control of enormous manufacturing companies in both hemispheres. The world is his field. No routine duties in connection with any of his score of companies sap his energy; he thinks, others act. More than that; he inspires, a hundred think, ten thousand act. Some of his great spirit filters down through all the organization, yet each man has his area of responsibility in which he is perfectly free to follow his own work in his own way. Such a policy develops men, broadens them, fits them for higher duties, and by the same means secures the realization of a great man's ideals. It is using other men, including their wills, in the execution of one's plan.

In politics the effect of this principle is somewhat obscured by the power of spoils, and yet partly organization and the evolution of the boss are a general fruit of democracy; and the boss at his best, selected by natural processes for his unusual power, force, capacity, not chosen by ballot of his peers, rules precisely upon the same lines as the captains of industry: he has the ability to think in the large and the power to impress multitudes of other men into his service; and his success is in direct ratio to his ability to do this without demanding any sacrifice of personal freedom. A difficult thing to do, this fitting of all shapes and sizes into an harmonious whole, while respecting absolutely the individuality of each: there are few successful bosses.

In his autobiography, Mr. Booker T. Washington says he has learned to disregard the old maxim, "If you want anything done, do it yourself," and is rather guided by this, "Do nothing yourself which someone else can do as well." The great problem of successful organization is to reduce to its narrowest limits the area of those things which one must do himself, and to enlarge correspondingly the zone of things which others can do sufficiently well. There is no real antagonism, however, between the two maxims Mr. Washington quotes. In a true sense he does the things which he has delegated to others. This is apparent if the question be asked, "Would his associates and assistants do those things were it not for him?" It is to him they owe the opportunity, the inspiration, the imparting of energy which have widened and deepened their lives and made possible their doing of duties, subordinate, it is true, to him, and yet on much higher planes of true freedom than had been possible without him. "Hitch your wagon to a star," says Emerson. Nothing so ennobles, enlarges, develops a man as hearty loyalty to one greater, stronger, better than himself.

It is significant that the same age which has seen man's respect for the individuality of his fellows reach its highest development in modern democracy, has also witnessed his greatest, most marvelous control over nature and men for his own purposes. We are being made in the image of God. If to be loyal to a great and good man is to open the door to growth, how much more will loyalty to the Infinite Spirit quicken all the springs of life. And life expresses itself along the parallel lines of individuality and of loyalty to one's Master. But we have seen that men of power—leaders, true "Kings"—get things done, bring their plans to pass, by using those who serve unconsciously as well as those who serve consciously and loyally. Accomplishing one's purpose by using others who are at the same time doing what they will—what else is divine sovereignty than that? What else than that is the greatest, the divinest exercise of true power in human organization?

All honor, then, to the man of power: he is an under-captain to whom the Great Captain has committed some important work. He is not a seeker after money or power or place for their own sake—a sordid man cannot be great. He is impelled by the great spirit within him seeking self-expression, which must create that lesser world around him which shall be to the man of power what the universe is to the Infinite Creator.

STEAM TURBINES

By FRANCIS HODGKINSON

Large steam turbine castings and parts of revolving-field turbine generators have been for a long time familiar objects around the shops at East Pittsburg, yet few realize the enormous development of work in this particular branch of engineering.

The results in the way of high steam economy that are being obtained, and the general performance of the machines in the field, have been particularly gratifying.

Several turbines of 5 500 kw capacity are under construction, and, in fact, are rapidly approaching completion. Still larger turbines are in course of design for stationary work as well as for marine propulsion.

There are in operation in the field and in course of construction at East Pittsburg, about 111 000 kilowatts of Westinghouse steam turbines.

A 5 500 kw turbine and its generator are shown in Fig. 1. Some few of its leading dimensions may be of interest:

Extreme length, including generator, 47 ft. 3 in.
Extreme width, " " 16 ft. 0 in.
Height above floor, " " 14 ft. 0 in.

The maximum overload capacity of this turbine will be about 13 000 hp. On this basis, we have over 17 hp. to the square foot, including the generator.

Some comparison of the space occupied by these units and reciprocating engines may be gathered from Figs. 4 and 5.

A steam turbine, for many reasons, makes an ideal engine. There are no rubbing surfaces except at the bearings, and these are found to be actually exempt from wear. The fact that there are no internal rubbing surfaces means a great deal. High superheat may be taken advantage of. Cylinder lubrication is unnecessary, hence the condensed exhaust steam is pure distilled water, and is the best kind of feed water for the boilers.

With turbines the cost of foundations is small; in fact, with

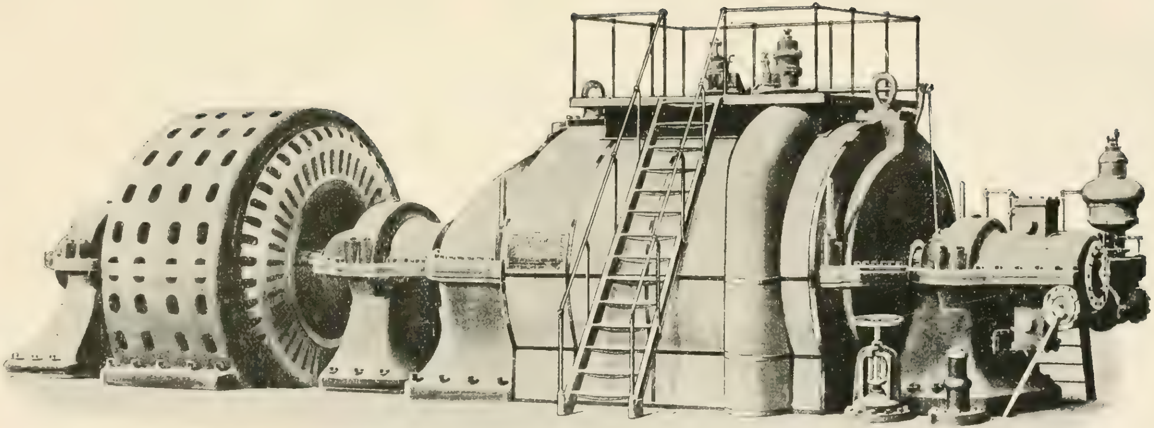


FIG. 1—5 500 KW STEAM TURBINE WITH GENERATOR

the exception of something that will hold up the weight of the turbine, none are needed. Holding-down bolts are never used except on ship board.

The foundations for the 1 500 kw turbine installed at Hartford, Conn., cost $300.00. The foundations for two 1 500 kw turbines at the Cleveland & Southwestern Traction Company at Elyria, Ohio, consist simply of two longitudinal walls for each turbine. They are made of concrete about one foot thick. Between the walls and underneath the turbines are located the condensers, which makes an ideally compact arrangement.

The machine shown in the frontispiece is a 1 000 kw turbine and generator photographed in the testing room. This machine has been for the past few months driving all the machinery of the new East Building of the Electric Company, as well as furnishing current for the office lighting. In this case the foundation consists of a concrete floor, reinforced with I-beams resting on brick piers, which are a considerable distance apart, to permit ready access to the condensing apparatus, which is directly below the turbine.

The theoretical construction of turbines has hardly a place in this article. A very excellent chapter on this subject, however, will be found in a little book by Robert M. Neilson, where the matter is treated on an entropy temperature basis.

It may be said that the laws that govern the design and form of the buckets and passages of water turbines are equally applicable to steam turbines. The difference lies in the fact that steam is elastic, while water is inelastic, and the former is a much less dense medium than water, and consequently attains much higher velocities.

To show the force of these remarks, compare the energy of one pound of steam and one pound of water at, say, 150 pounds per square inch gauge pressure, discharging into a 28-inch vacuum, or 1 pound absolute pressure. The water will be theoretically capable of developing 379 foot pounds of energy and will discharge with a velocity of about 156 feet per second. The best speed of a wheel of the Pelton type of, say, 1 foot in diameter, to deal with this velocity, would be 1490 revolutions per minute—a very comfortable speed. The 1 pound of steam, on the other hand, will correspondingly develop 250 000 foot pounds of energy, and will have a theoretical discharge velocity of over 4 000 feet per second.

A bucket wheel of the dimensions quoted above should now revolve at 38 300 revolutions per minute, a speed at which difficulty would be found in designing a strong enough wheel.

The analogy between a water and a steam turbine is not entirely complete. In the water turbine the functions are kinetic only. The velocity due to the fall is converted into work. In the steam turbine there is first a conversion of heat into energy, when the steam does work upon itself and attains velocity; then, after this, the function is kinetic and is the same as in the case of the water wheel.

The phenomenon of the steam jet has, until lately, been surrounded with a good deal of mystery—but it is now generally understood. Its investigation, however, forms a most interesting study.

The function of the nozzle is to direct a jet of fluid in a predetermined direction with the greatest velocity attainable. In the case of a steam jet, it is obvious that the steam must be thoroughly expanded within the nozzle, so that the energy due to the expansion of the steam may be utilized in accelerating the jet to the maximum possible velocity. If any expansion takes place after the steam has passed the nozzle, this expansion is uncontrolled by the walls of the nozzle and consequently will be in other directions besides the one in line with the axis of the jet. When the pressure into which the nozzle is discharging is greater than 56 per cent. of the initial pressure, all that is required to satisfactorily expand the steam is an orifice having a well rounded entrance. But should such a nozzle be subjected to a greater range of pressure than the above, that is to say, should the discharge pressure be less than 56 per cent. of the initial pressure, then the expansion of the steam would not be complete within the nozzle; there would be considerable lateral expansion outside of it. In this case a nozzle, to give the best results, must be of some length and have divergent walls, such that it is smallest at the rounded entrance and then becomes of increasing cross section until the end is reached.

The reason for the divergence is plain when it is considered that the work done by the expanding steam varies something like in direct proportion to the number of expansions, and also varies directly as the square of the velocity. The volume of the steam therefore increases much more rapidly than the velocity, and room must be provided at the outer end of the nozzle to permit of the proper expansion of the steam. The expansion of steam in a nozzle follows closely the adiabatic line.

Considering this subject further, suppose we have an elementary turbine like that made use of in the comparison between a steam and water turbine, consisting of a nozzle which directs a jet of steam against the paddles of a rapidly revolving wheel. The steam flows through the nozzle, and if this is properly constructed it will be thoroughly expanded within the nozzle from the initial pressure to the pressure of the exhaust, and the energy thus given up by the expansion will be utilized in accelerating the jet. Therefore, when the steam arrives at the end of the nozzle, its heat energy will be expended and converted into kinetic energy. There will be a fall of temperature, and as no heat is added and the expansion is adiabatic, some of the latent heat of steam will be given up as work, which, of course, will result in considerable condensation. This condensation would amount to 23 per cent. by weight, if the nozzle were perfect and expanded from 150 pounds gauge pressure to 28 inches vacuum.

If this jet were brought to rest within a closed vessel where a pressure is maintained corresponding to the 28 inches vacuum, instead of against the paddles of a wheel, the kinetic energy of the jet would be re-converted back into heat, for there has been no escape or adding to of heat. The expanded steam within the closed vessel would then become considerably superheated. This is the principle made use of in the well-known Carpenter throttling calorimeter.

A point of much interest in this connection was pointed out by Prof. W. H. Watkinson, of England. If, after the energy in the jet is converted into velocity, we were to separate therefrom the water of condensation and then bring the jet to rest in a closed vessel, as above, the temperature in this vessel would rise far higher than the original temperature of the steam. He shows that steam of 160 lbs. absolute pressure, corresponding to 363° Fahrenheit, expanding to atmosphere, would rise to 472° Fahrenheit in the chamber. The expanded steam, therefore, would be 109° hotter than the steam was originally. Prof. Watkinson naively remarks in his paper, "The question as to whether the water can be completely removed or not, and the best means of removing it, do not come within the scope of the present paper."

To return to the subject of an elementary turbine: if the form and speed of the paddles were such that they might wholly absorb the velocity of the jet without friction, the condition of the steam leaving the buckets would be the same as when it left the jet, except that it would no longer have velocity, but as a matter of fact there are many causes of loss. The velocity may not be entirely absorbed; that is to say, the steam may issue from the buckets of the wheel with considerable velocity, which is a direct loss. There will be a reduction of velocity due to surface friction and eddies of steam in the buckets, which results in heating up the steam, causing a re-evaporation of some of the water condensed in the nozzle, which to a lesser degree is the same as the action of steam in a throttling calorimeter, as before described.

If the above described form of turbine had its nozzles mounted on a wheel, no buckets would be necessary, but in order to be equal in efficiency, the wheel would have to revolve at twice the speed of that in the case we have considered.

The above forms the fundamental principle of steam turbines. Probably the turbine manufactured by The Westinghouse Machine Company, in outward appearances, resembles the above type less than any other type of turbine.

The great feature of this turbine is that the energy is fractionally abstracted from the steam. The steam enters at the high pressure end and travels to the exhaust. In its passage are arranged several rows of turbine blades, at each of which the steam falls in pressure by steps, so to speak, giving up part of its energy at each successive step.

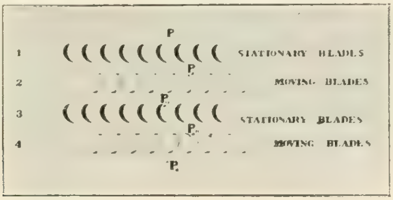


FIG. 2

The form of the blades is shown diagramatically in Fig. 2. The steam, in expanding from state P to P_1, attains a velocity and strikes the movable blades 2, causing them to revolve. It again expands from P_1 to P_2, attaining another velocity which, reacting on row 2, again causes it to revolve. Thus the motion of the revolving blades is due to two causes: one, the steam striking them; and the other, the steam leaving them.

The velocity of the steam, it will be plainly seen, may be controlled within whatever limits desirable, according to the proportioning of the turbine. In practice, these velocities are from 150 to 600 feet per second, which is a speed comparatively slow and one which it has been found will cause absolutely no erosion of the buckets, and at which the skin friction of the operating fluid passing over the bucket surfaces will cause an inappreciable amount of loss.

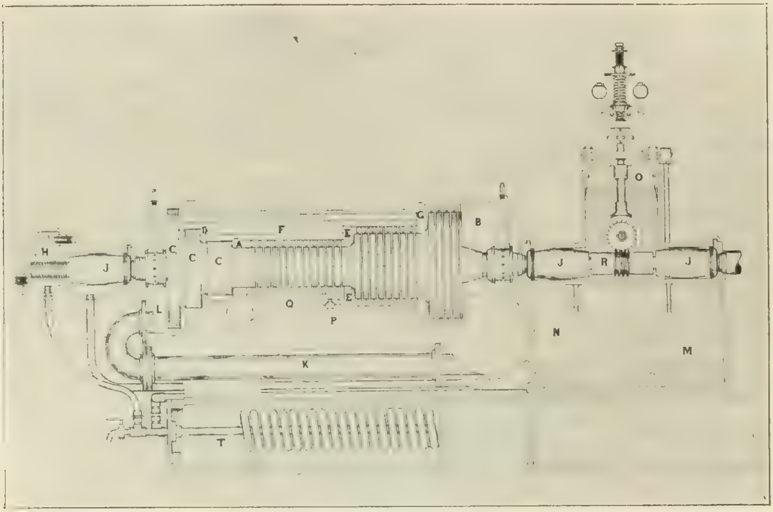


FIG. 3

Fig. 3 shows a longitudinal section through a turbine, the steam entering at *A* and exhausting at *B*. It shows the side clearance between the blades, which is never less than $\frac{1}{8}$ inch and is, in the larger machines, as much as $\frac{1}{2}$ inch, so that danger of collison between the moving and stationary element is very remote.

However, "The proof of the pudding is in the eating thereof." The Westinghouse Machine Company have installed a testing room for their steam turbine work, by means of which turbines are thoroughly tested and their economy tested beyond dispute. They have condenser capacity for condensing 60,000 pounds of steam an hour, which permits of testing turbines of large powers, up to their ultimate capacity. All turbines are thoroughly tested, and these tests are frequently carried out in the presence of the purchaser's representative, who thus obtains an exact knowldge of the performance of the apparatus.

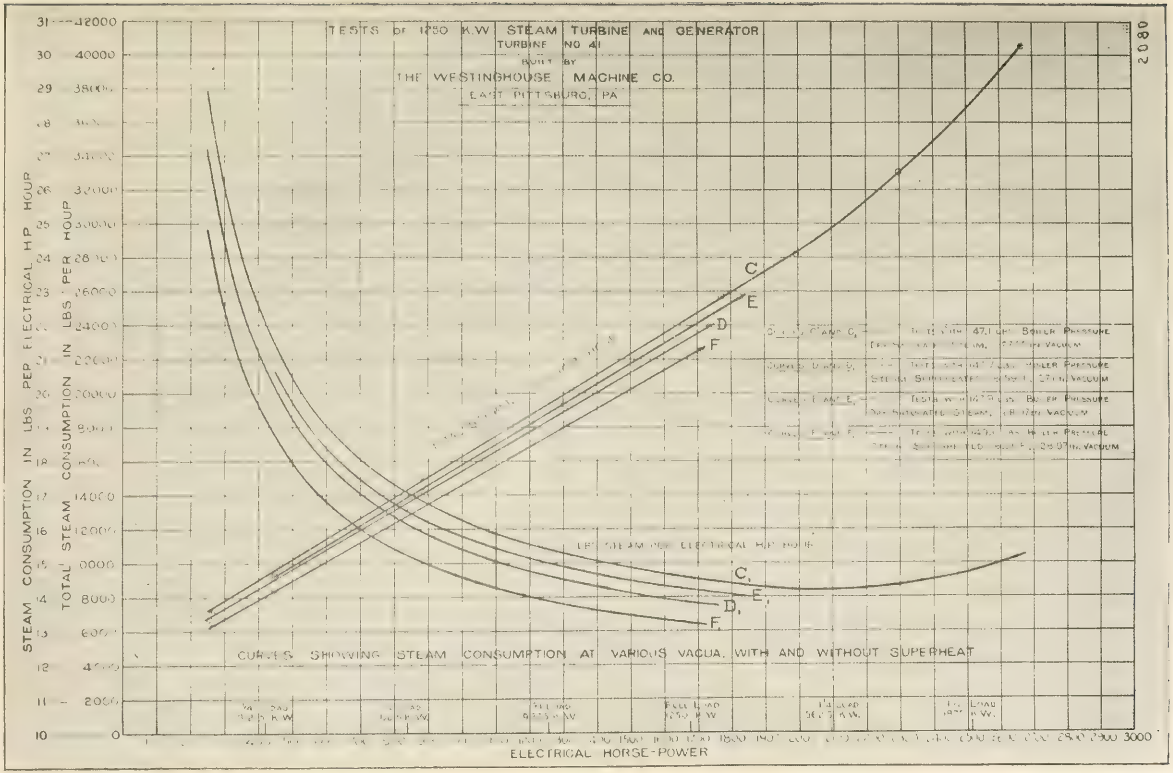

TESTS OF 1250 K.W. STEAM TURBINE AND GENERATOR
TURBINE NO 41
BUILT BY
THE WESTINGHOUSE MACHINE CO.
EAST PITTSBURG, PA
2080
STEAM CONSUMPTION IN LBS. PER ELECTRICAL H.P. HOUR
TOTAL STEAM CONSUMPTION IN LBS. PER HOUR
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000
36000
38000
40000
42000
C
E
D
F
C,
E,
D,
F,
LBS. STEAM PER ELECTRICAL H.P. HOUR
47.1 LBS. BOILER PRESSURE
VACUUM
STEAM SUPERHEATED
27 IN. VACUUM
TESTS
BOILER PRESSURE
SATURATED STEAM
VACUUM
BOILER PRESSURE
28.07 IN. VACUUM
CURVES SHOWING STEAM CONSUMPTION AT VARIOUS VACUA, WITH AND WITHOUT SUPERHEAT
FULL LOAD
1250 K.W.
1875 K.W.
1800
2800
2900
3000
ELECTRICAL HORSE-POWER

FIG. 6

Hereto are added some results of tests which have been selected, more or less at random, from records of from 900 to 1 000 tests of turbines of various sizes.

Fig. 6 shows the results of a series of tests on one of the turbines for the lighting of the Interborough Rapid Transit Company of New York. These tests were witnessed and verified by engineers of the staff of Julian Kennedy, Esq., of Pittsburg.

One curve shows how the economy of the turbine holds up with overloads.

Some tests were lately made by Mr. F. W. Dean, of the firm of Dean & Main, on a 400 kw turbine, No. 55, showing the following results:

Boiler Pressure	Degrees Fahrenheit Superheat	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
151	182	28	3,481	763.5	11.25
154	181	28.1	3,543	592.3	11.45

The same turbine without superheat:

Boiler Pressure	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
153	28	3,481	728.4	13.63
154	28	3,545	593.2	13.91
156	27.9	3,584	448	14.48
156	28	3,602	241.3	16.06

Brake test of a 400 kw turbine, No. 52, showing the range of overload on a turbine, and the economy at such overloads:

Boiler Pressure	Degrees Fahrenheit Superheat	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
150	45	28	3,549	258.1	15.55
151	41.3	28	3,526	424.6	14.16
152	44.7	28	3,511	621.5	13.56
150	41.8	28	3,478	755.9	13.23
150	44	28	3,436	824.6	13.36
143	44.6	27.8	3,414	1,028.2	14.13

Brake test of a 400 kw turbine, No. 54, with 150 lbs. boiler pressure, 150° F. superheat and 28″ vacuum:

Boiler Pressure	Degrees Fahrenheit Superheat	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
151	139	28	3,537	626	11.86
149	158	28	3,586	451	11.86
150	150	28	3,595	296.8	13.2

Electrical test of a 400 kw turbine, No. 39, with 150 lbs. boiler pressure, 100° F. superheat and 27″ vacuum:

Boiler Pressure	Degrees Fahrenheit Superheat	Vacuum ref. to 30″ bar.	Revolutions per minute	Load in kilowatts	Electrical Horse Power	Lbs. Steam per elect. hp hour
155	97.6	27	3,482	411.12	551.1	13.47
147	104.2	27	3,509	311.72	417.9	13 83
155	103	27	3,530	219	293.7	14.54

Test of a 1 500 kw turbine, No. 31, with 150 lbs. boiler pressure superheated 25° Fahrenheit and $27\frac{1}{2}$″ vacuum:

Boiler Pressure	Degrees Fahrenheit Superheat	Vacuum ref. to 30″ bar.	Revolutions per minute	Load in kilowatts	Electrical Horse Power	Lbs. Steam per elect. hp hour
146	28	27.5	1,476	1,557.6	2,087.8	13.67
144	28.4	27.5	1,490	1,239.8	1,662.0	13.94
147	27.6	27.5	1,502	767 9	1,028.1	16.05
155	29.9	27.5	1,507	383.4	513.9	20.04

An electrical test of a 1 500 kw turbine, No. 32, with 150 lbs. boiler pressure, dry saturated steam and 27″ vacuum:

Boiler Pressure	Quality of Steam	Vacuum ref. to 30″ bar.	Revolutions per minute	Load in kilowatts	Electrical Horse Power	Lbs. Steam per elect. hp hour
148	.992	27.0	1,186	1,530	2,051	14.8
146	.994	27.0	1,202	1,154.5	1,547.7	15.01
149	.992	27.1	1,206	792.1	1,061.6	17.21
149	.991	27.1	1,221	392.5	526.14	20.19

The results given above are, for the most part, under good operating conditions, that is, high vacuum and superheat. A high vacuum is more desirable for a steam turbine than for a reciprocating engine, because the turbine can successfully expand steam to the limits of the condenser pressure without the losses encountered with a reciprocating engine, such as the friction due to an enormous increase in the size of the low-pressure cylinder, and the condensation and re-evaporation losses due to the cylinder being alternately filled with live and exhaust steam. The latter loss is aggravated by the fact that the temperature of steam falls much more rapidly as it reaches the low pressures.

Some types of turbines are unable to show any kind of economy except with the highest vacuum, due to the fact of having wheels revolving in the more or less dense medium of the exhaust pressure. The Westinghouse turbine, however, has no such limitations. It can show an admirable performance with poor vacuum and low boiler pressure, as is shown by the following tests:

Brake test of a 400 kw turbine, No. 28, with 125 lbs. boiler pressure, dry saturated steam and 26″ vacuum:

Boiler Pressure	Quality of Steam	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
126	1.0015	26	3,536	580	15.41
125	.999	26	3,555	457.2	16.36
131	.999	26	3,545	326	17.89

Electrical test of a 1 500 kw turbine, No. 17, with 150 lbs. boiler pressure, dry saturated steam and 25″ vacuum:

Boiler Pressure	Vacuum ref. to 30″ bar.	Revolutions per minute	Load in kilowatts	Electrical Horse Power	Lbs. Steam per elect. hp hour
149	25.0	1,498	1,506	2,015	16.33
150	25.0	1,503	914	1,224	18.82
151	25.2	1,500	310	417	28.1

Brake test on a 400 kw turbine, No. 51, with 150 lbs. boiler pressure, dry saturated steam and 26″ vacuum:

Boiler Pressure	Quality of Steam	Vacuum ref. to 30″ bar.	Revolutions per minute	Brake Horse Power	Lbs. Steam per brake hp hour
152	.999	26.1	3,541	610.8	14.59
151	1.001	26.1	3,599	451.4	15.32
150	1.002	26.1	3,593	266.1	17.06

Electrical test of a 1 000 kw turbine, No. 15, with 130 lbs. boiler pressure, dry saturated steam and 27″ vacuum:

Boiler Pressure	Quality of Steam	Vacuum ref. to 30″ bar.	Revolutions per minute	Load in kilowatts	Electrical Horse Power	Lbs. Steam per elect. hp hour
132	.999	27.0	1,489	1,101.7	1,476.8	14.9
133	.999	27.0	1,498	786.6	1,054.5	15.99
134	.999	27.1	1,508	530.7	711.4	17.95
139	.997	26.8	1,513	380.01	509.4	20.75

The above test may be of interest, because it shows the economy of the turbine above referred to, which at present is operating in the works of the Westinghouse Electric & Manufacturing Company.

FACTORY TESTING OF ELECTRICAL MACHINERY—II

By R. E. WORKMAN

IN ALL testing work it is necessary to bear in mind that precision in the performance of any part of the work need not be greater than is consistent with that desired in the results. By attempting more than this nothing is gained and much time and effort wasted. Take as an example a saturation curve reaching a maximum of 125 volts, plotted on cross-section paper, one division representing two volts. On this scale it is not possible to read with greater precision than to two-tenths of a volt, and in reading a voltmeter or correcting readings already taken for inaccuracies of the scale of the instrument, it is useless to record anything beyond the first place of decimals.

A very important point in the reading of instruments is the integrity of the observer. Inaccurate reading and mistakes in reading may be largely eliminated by taking the mean of a number of readings, but a bias on the part of the observer cannot be counteracted in this way. A perfect observer would be one who had no ideas of his own, whose one faculty was the accurate noting of the position of the needle of an instrument and of mentally subdividing a small division into tenths. He would never have any idea of the results expected, would not be allowed to plot his results on paper to see that they made a smooth curve, in short, he would be nothing more than a machine. But, as the observer must also be the tester, and the tester must have all the faculties denied to the perfect observer, much depends on his *integrity* and *strength of will.* The tester must be ready to note any result, however unexpected, but he should not stop there; he should trace out the apparent anomaly and find whether the cause is an error in his ideas, or is due to an unnoticed change in the conditions of the test. Where readings are taken to plot a curve whose form is practically known, it will be well for the tester to use cross-section paper and mark down the points as they are taken. Mistakes may often be detected in this way,

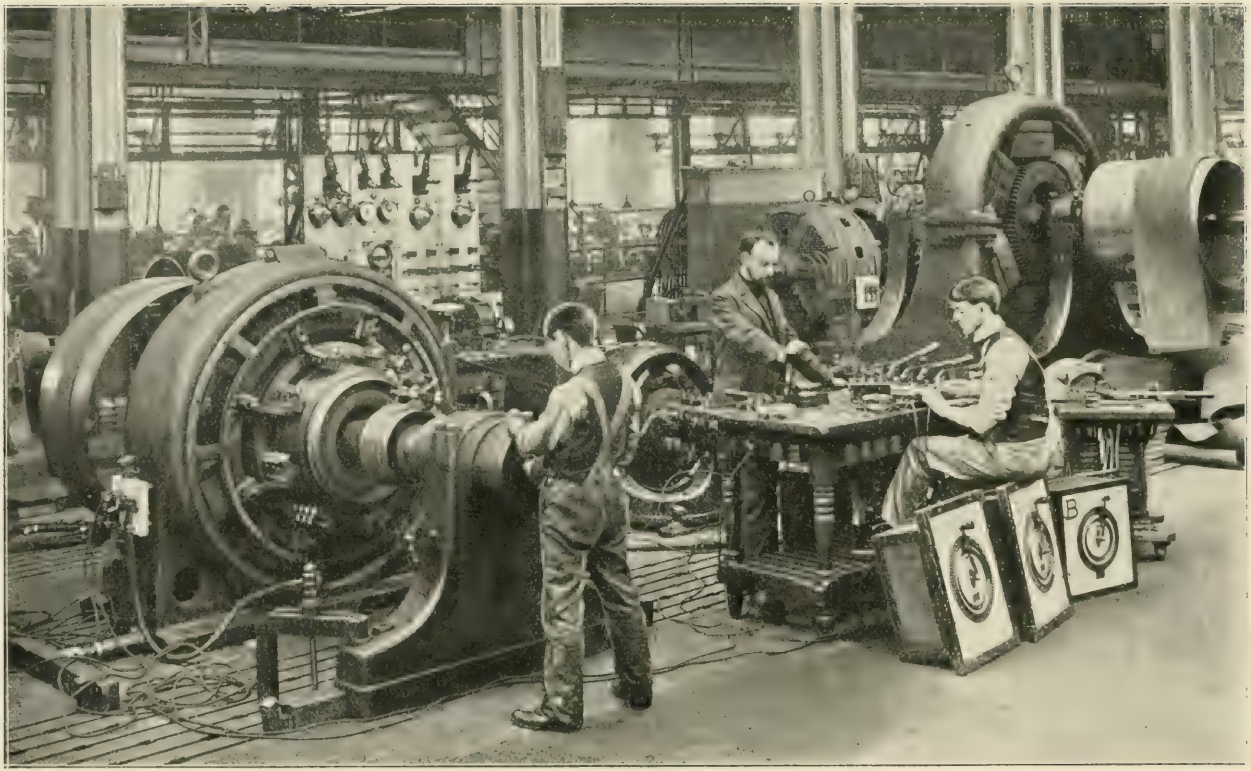


FIG. 6—IRON LOSS, FRICTION AND SATURATION TEST

and, by their elimination, much time may be saved and fewer points will be necessary to determine the curve. A good deal of caution is necessary in the use of approximate methods of testing, to see that the errors introduced by assumptions of approximation do not exceed the required limits. This danger occurs in one or two of the ordinary tests, and will be mentioned in its place.

The question of precision comes in again in the working up of results from test readings. Here it is only necessary to mention that in correcting the readings of instruments, it is useless to go beyond the accuracy of the instruments themselves, or beyond the precision desired in the result. Where products, quotients, etc., are to be taken, the slide rule is quite precise enough, reading, as it is possible to read it, to the third significant figure. The other sources of error in calculating work are mistakes in arithmetic and mistakes in the plotting of curves. These may be largely eliminated by a proper system of checking.

DIRECT-CURRENT MACHINERY

The testing of direct-current generators and motors will be divided into two groups:—EXPERIMENTAL and COMMERCIAL, as outlined in the introduction.

EXPERIMENTAL TESTING

The tests commonly made are given in Table I, of the introduction. The order of tests given there is not necessarily that in which the tests are performed, this order being determined by convenience, as follows:

Tests made with the machine at rest.

Tests made with the machine driven on open circuit by a separate driving motor.

Tests made with the machine loaded as in service.

The tests will be described in the order in which they are performed.

LOSS TESTS:—The losses in direct-current machines are of three kinds:

(a) Copper loss.
(b) Iron loss.
(c) Friction loss.

(*a*) *Copper Loss*—The loss in the copper circuits of the machine is due to their resistance and can be determined electrically with the machine at rest. It is only necessary to determine the resistance of the different windings of the machine and from these the loss can be calculated by multiplying the resistance of the winding by the square of the current flowing through it.

Resistances are determined by the fall of potential method. This method, the accuracy of which is well within the required limit, is by far the most convenient one. The instruments required are those used in ordinary testing. The "bridge" methods, which might be used instead, are more accurate in their proper place, and should be used for all delicate measurements, such as that of the resistivity of a metal. The instruments used in bridge methods are more easily injured and require more care in handling than those used in the fall of potential methods.

There are two methods of making the fall of potential test; one in which an ammeter and a voltmeter are used to measure the current in the circuit and the fall of potential across the resistance, another in which a standard resistance is put in series with that to be measured, and the ratio of the fall of potential across the resistance to be measured to that across the standard resistance is determined.

One advantage of the former method is that the readings on voltmeter and ammeter may be taken simultaneously, thus eliminating the effect of a varying voltage in the testing circuit; on the other hand, although the latter method has not this advantage, in it only one instrument is used and the ratio of the two readings multiplied by the resistance of the standard resistance gives, directly, the resistance required.

(i) *Preparations for Test* (With Ammeter and Voltmeter)—The connections are shown on Fig. 3 which needs little further explanation. The resistance marked "rack" may be of any suitable form, such as an ordinary field regulating rheostat or the iron wire racks used for load in the smaller machines. A thermometer must be hung up near the machine, or, if there is any chance of the different parts of the machine having temperatures other than that of the air, a thermometer should be placed against each of the windings whose resistance is to be measured.

Conduct of Test—A high resistance should be put in the rack to start with. The Switch S_1 must be thrown in to complete the circuit. The voltmeter should be connected up on the high scale, long wires being used, with metal points, held on the ends of the resistance to be measured. If the voltmeter deflection is in the wrong direction it is simply necessary to reverse the leads. Before opening the short circuit switch S_2 the ammeter should be observed, and if it tends in the wrong direction the leads should be reversed. The rack resistance may now be adjusted to give suitable readings on voltmeter and ammeter and a series of about four readings taken of the volts and amperes, varying the current slightly after each. The voltmeter and ammeter must be read simultaneously owing to the possible fluctuations in the voltage of the supply circuit.

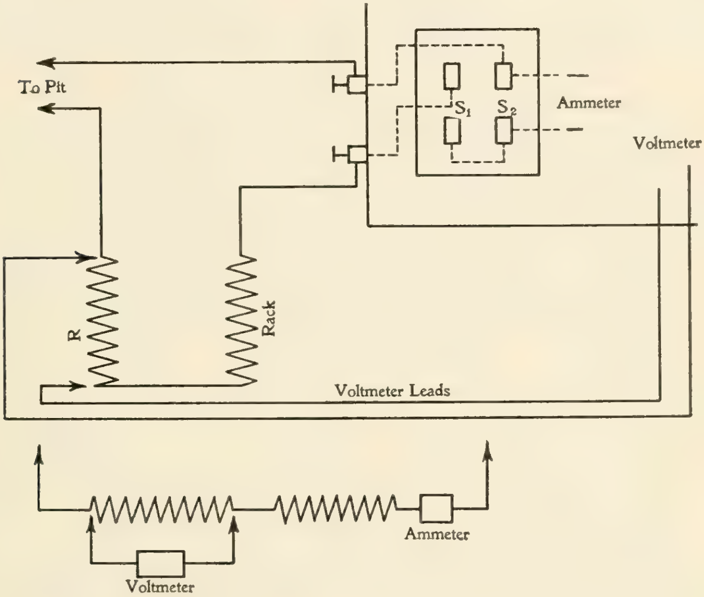


FIG. 3—CONNECTIONS FOR RESISTANCE TEST

(ii) (With Standard Resistance)—The only difference in the connections is that the standard resistance is put into the circuit in series. Readings are taken of the fall of potential across the resistance to be measured and across the standard resistance for different currents.

The resistance is found from this ratio by taking the product of the ratio and the resistance of the standard. This follows from Ohm's Law.

Precautions to be Observed—In all cases it is necessary to be very careful not to ground one of the voltmeter points, as this may cause the full voltage to be thrown across the voltmeter, throwing the needle up against the stop and bending it. The reason for this may be seen from the diagram at the foot of Fig. 3. If there is a ground on the line to the right of the figure and the voltmeter point to the right is grounded, the whole voltage will be thrown across the voltmeter. In taking the resistance of a *shunt field winding* it is necessary to remove the voltmeter points before opening the circuit, as, on doing this, the difference of potential rises very largely owing to the collapse of the magnetic field. In taking the resistance of a *series field winding*, in order to avoid errors due to the resistance of the leads and bad temporary connections, the voltmeter points should be held right on the ends of the coils. In taking the resistance of an *armature,* special precautions are necessary.

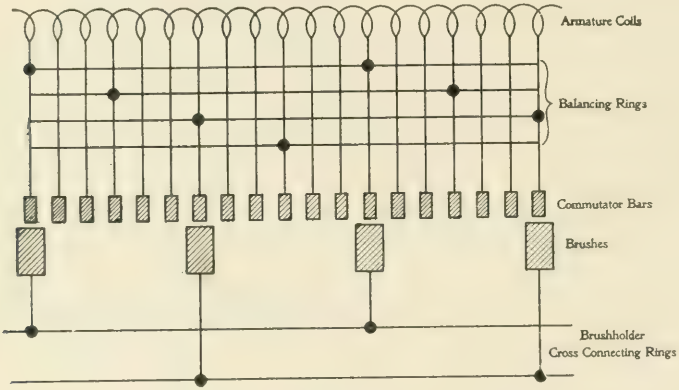


FIG. 4

(i) Multiple Wound Armatures—Where there are balancing rings the brushes should be so set that they connect as directly as possible with a pair of balancing rings. If the balancing rings are on the commutator end of the armature, this is done simply by setting the brushes on commutator bars which are connected to balancing rings. If the rings are on the back of the armature the bars connected to them must be traced to the commutator. Check readings should be taken on another pair of balancing rings, and a mean taken between the two sets. This position of the balancing rings eliminates the effect of unequal contact between the brushes and the commutator causing different currents in the different circuits of the armature.

This will be seen in Fig. 4, which is a diagrammatic representation of a development of the armature windings of a machine with balancing rings. It will be seen that, when the brushes are on communtator bars which are cross-connected by balancing rings, all the parallel circuits of the armature are connected in multiple independently of the brushes. As the voltage drop is taken across the commutator, and not across the brushes, this obviously eliminates all effect from unequal contact between brushes and commutator. For the same reason in machines which do not have balancing rings, it is necessary to see that all brushes are evenly ground and make equally good contact with the surface of the commutator.

(ii) Series Wound Armatures—No special precautions are necessary except that the voltmeter points must be held on the commutator in an axial plane with the center of the brush. The resistance is measured, of course, between adjacent brush holders.

Working up Results—The relation of the resistance to the results of this test depends simply on Ohm's Law.

First of all it is necessary to correct the readings from the calibration tables corresponding to the particular instruments used. The division of volts by amperes is then carried out, giving the resistance. A mean of the values found from the four sets of readings is taken. It is now necessary to alter the resistance found to its equivalent at 25° C. To do this it is assumed that the resistance of copper rises .42% per degree Centigrade. Thus the value of resistance found must have .42% added to it for every degree Centigrade of the excess of 25° C over the temperature of the test.

Example.—500 kw compound wound, belted generator, 550 volts, 514 revolutions per minute, 6 poles. Air temperature 23.5° C.

Resistance of series field windings:

AMPERES		VOLTS		Resistance at 23.5°C.
Observed	Corrected	Observed	Corrected	
150	148.5	.241	.245	.00165 ohms.
132	130.5	.212	.215	.00165 “
114	112.5	.183	.186	.00165 “

Therefore the resistance at 25° C. will be .00166 ohms.

(b) Iron Loss—Iron losses are supplied mechanically; they manifest themselves in the form of a torque on the armature and are therefore measured by measuring the input to a motor driving the machine to be tested at its required speed. Iron losses are due to two causes—hysteresis and eddy currents.

Hysteresis is a property of iron in virtue of which it resists change in intensity of a magnetic field within it. It is sometimes called "molecular magnetic friction," owing to its resemblance to viscosity, which, when it exists in a liquid, resists change of form as hysteresis resists change in magnetic intensity. As in the case of viscosity, the work done in overcoming hysteresis varies directly as the speed with which it is overcome. It will thus be seen that the hysteresis loss is a purely magnetic loss.

Eddy currents are currents induced in a mass of magnetized iron when the magnetic intensity is changed. They are due to differences of potential, induced by these changes in the magnetic intensity, between different parts of the iron. These cause currents to circulate which generate heat in the same way as currents in a copper circuit. This loss is dependent on the shape of the piece of metal, and is a purely electrical loss.

(c) Friction Losses—These are likewise supplied mechanically and obtained by measuring the input to a driving motor. They are divided into two groups:

Brush friction.

Bearing friction and windage.

It is convenient to measure the iron loss and friction loss during the same test, as will be seen from the following scheme:

$$\begin{array}{c}\text{Total Energy Supplied}\\ \text{to Driving Motor}\\ \text{Armature}\end{array}\begin{cases}\text{Losses in Driven Machine}\begin{cases}\text{Iron Loss}\\ \text{Brush Friction}\\ \text{Bearing Friction}\\ \text{and Windage}\end{cases}\\ \\ \text{Losses in Driving Motor Armature}\end{cases}$$

Fig. 5

Suppose the motor to be driving the machine under test at its proper speed as a generator on open circuit, with a given known shunt field current in the generator. The energy of the motor, if measured, may be analyzed as shown in Fig. 5. If the field circuit of the generator be now opened, the energy of the motor will be reduced by an amount equal to the iron loss corresponding to the generator voltage and field current. Thus, if the input of the motor be subtracted from that of the first case, the remainder may be taken as the IRON LOSS of the generator. If now the brushes of the generator be lifted, the result of taking the difference between the results of the third and second readings will give the BRUSH FRICTION. It now remains to take the belt off the motor and find its input without any load. This, when subtracted from the third reading, gives the BEARING FRICTION and WINDAGE of the generator. Along with the loss test is taken the SATURATION, which will be described later, and which is taken with it simply owing to the fact that a driving motor is required, as with the loss tests. The readings taken are the TERMINAL VOLTAGE and the SHUNT FIELD CURRENT of the machine for each loss reading.

Preparations for Test—The machine to be tested must be belted to a small direct-current shunt wound motor as shown in Fig. 6, to run at its designed speed. The table generally used is that shown on Fig. 7, the connections being made as indicated. The six switches on the left are for the driving motor. Three rheostats are used, (1) in the field of the driving motor to vary its speed; (2) in the field of the shop generator to hold the voltage steady while taking a reading; (3) in the field of the driven machine to vary the field current.

Conduct of Test—The motor is started by throwing in switch 4, then 1 and 2, completing the shunt circuit of the motor. The starting rheostat must then be set so that its resistance is all in and the switch 5 closed, when the motor should start. As it picks up speed, the starting resistance must be cut out and finally switch 3 thrown in.

It is now necessary to set the brushes of the machine at the "no load neutral" or the position on the commutator at which the potential of adjacent bars is equal. In most machines of modern design, where a commutator bar has a position midway between the armature conductors with which it is connected, this position is under the center line of the pole. This position is accurately located in the following manner: the field circuit of the generator is closed and its voltage raised to about its proper value, voltmeter points leading to a voltmeter which reads up to about fif-

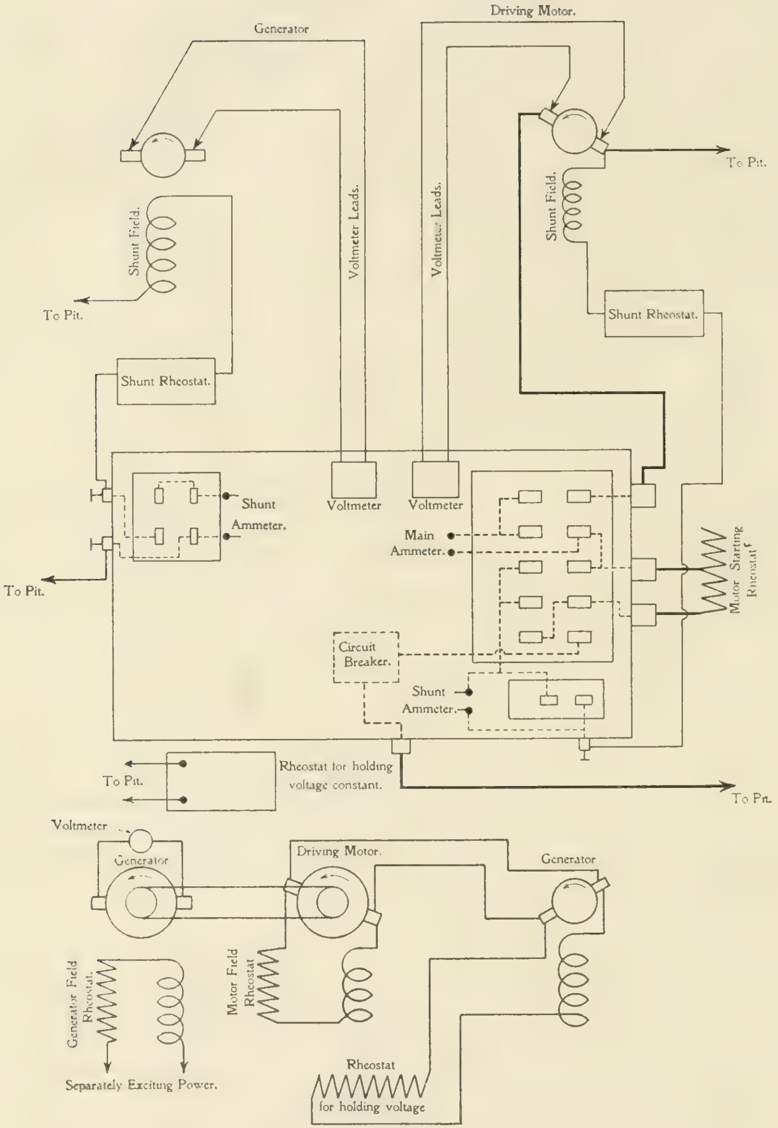


FIG. 7—CONNECTIONS FOR IRON LOSS, FRICTION AND SATURATION TEST

teen volts, are held as indicated in Fig. 8, being held at a distance from one another about equal to the breadth of a commutator bar. These points are then moved back and forth circumferentially till the position is reached at which the voltmeter reads zero, this position noted and the brushes set. Throughout the test the speed of the generator is held constant.

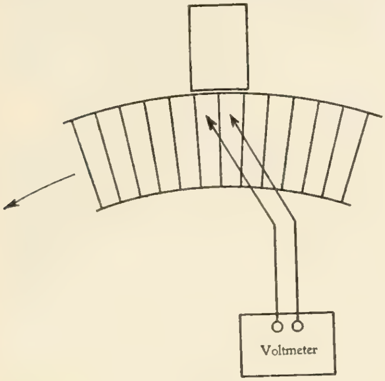


FIG. 8

The readings taken in the loss test are line voltage and armature amperes on the motor, and speed, terminal volts and shunt field amperes on the generator. These readings are taken under the following different conditions:

(i) With no field current on the generator, this being repeated three or four times during the test.

(ii) A number of readings with varying field currents, on the generator, one being taken at the proper voltage of the machine.

(iii) A reading with the brushes up and no field current on the generator.

(iv) A reading with the brushes up and the generator field current such as to give the proper voltage on the generator, i. e., the same as in the full voltage reading in (iii).

(v) A reading of the motor input with the belt off.

Of the losses in the motor, the only one which changes appreciably with a change of current is the armature $I^2 R$ loss. The friction loss is constant, because the speed is constant, and the iron loss is practically constant because the field strength is practically constant. As the change in the motor losses due to $I^2 R$ loss is not generally taken account of, the iron loss found for the generator will be higher than the actual. As a rule, this error is negligible small, but, if very accurate results are desired, or if a driving motor too small for the test is the only one to be obtained, it is simply necessary to subtract the armature $I^2 R$ loss from the motor input for each reading, and proceed as before.

If the generator field current is raised by accident above the value at which a reading is to be taken, the voltage should be reduced far below and then brought up again. These curves are always taken with an increasing saturation, the losses for a given votage being slightly lower with a decreasing saturation, owing to the retentivity of the magnetic circuit.

The check readings on the motor input with no current in the generator field are taken so as to make sure that there has been no change in the bearing friction, the brush friction, or the residual field due to the retentivity of the magnets. The check reading taken with the brushes up on the generator and full voltage field current, is a check on the position of the brushes. If the input found is subtracted from that with the brushes down and the same field current, the result should be the brush friction loss. If it is greatly different from the value found with no field current, it may be assumed that the brush position has been wrong and that currents have been circulating in the armature.

Working up Results—Example:

The same machine whose resistances have been found as described above.

Iron loss, friction and saturation test:

	MOTOR				GENERATOR	
	Volts	Armature Amperes	Watts	Speed	Volts	Field Ampers
(i)	110	61	6,710	516	7	0
(ii)	110	141	15,510	514	554	5.3
(iii)	110	38	4,180	515	.....	0
(iv)	110	112	12,320	514	.....	5.3
(v)	110	20	2,200	.....	.....	.....

(i) The motor driving the generator without field current, supplying the friction and windage losses in the generator.

(ii) The motor driving the generator with the field required to give full voltage on open circuit.

(iii) The motor driving the generator with brushes up and no field current.

(iv) The motor driving the generator with brushes up and full field current.

(v) Motor readings with the belt off.

If (i) is subtracted from (ii) the iron loss corresponding to a voltage of 554 is found.

If (iii) is subtracted from (i) the brush friction loss is found.

If (iv) is subtracted from (ii) a check is made on the brush position as described above.

If (v) is subtracted from (iii) the bearing friction and windage loss is found.

The results obtained are:

Iron loss at 554 volts=8.8 kilowatts.

Brush friction from (iii)=2.53 kilowatts.

Brush friction from (iv)=3.19 kilowatts.

Bearing friction and windage=1.98 kilowatts.

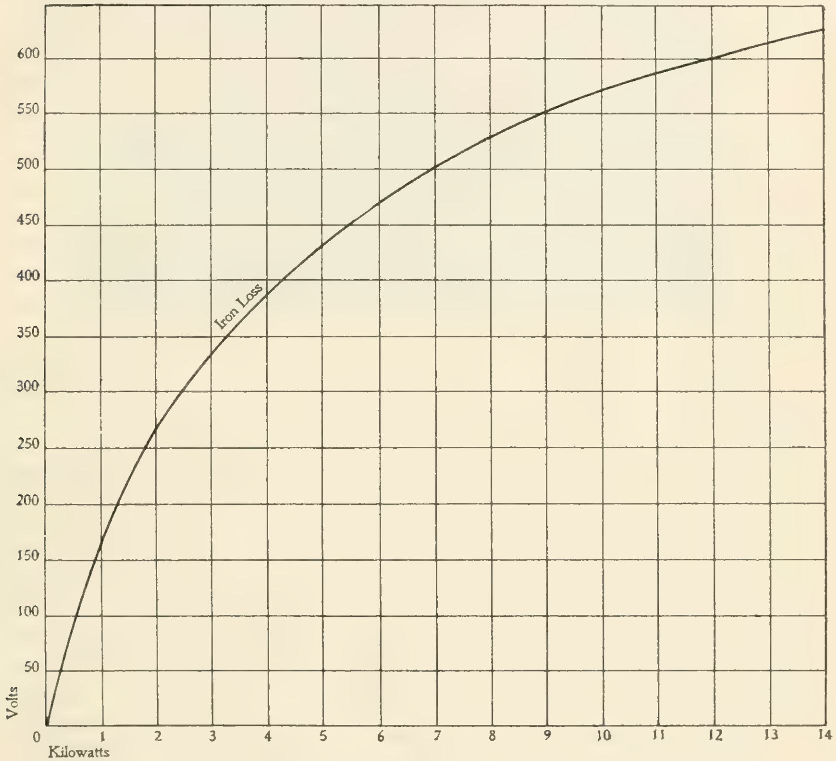


FIG. 9—IRON LOSS CURVE

It will be seen from the two different values obtained for the brush friction that the brush position was not quite correct, there being 660 watts lost, due to circulating currents in the armature and brushes at full voltage.

The complete iron loss curve from this test is given in Fig. 9 which shows the method of plotting.

FOUNDRY PRACTICE WITH COPPER AND ITS ALLOY

By W. J. REARDON, General Foreman of the Brass Foundry of the Electric Company

A Paper Presented Before the MATERIALS SECTION of THE ELECTRIC CLUB, Dec. 23, 1903
Abstracted by A. E. FLOWERS

COPPER—Copper and its alloys are very important materials from the standpoint of the electrical engineer, and since a large part of these materials must be shaped by casting, the foundry practice in connection with them becomes important.

The process of casting is apparently simple: copper is not hard to melt and, when melted, it is not difficut to pour the fluid mass into a properly shaped receptacle. Sad experience has, however, shown the foundryman that good results cannot be obtained by any haphazard method.

The first requirement is that THE COPPER MUST BE HEATED TO EXACTLY THE RIGHT TEMPERATURE.

If the heating be prolonged, and the metal brought to a bright red heat, it becomes "soaked," as it is called. After being poured, there is a period of quietness and all seems well; suddenly there is a small explosion; the sand is blown from the flask and the metal at the gate flies in all directions. When the casting is examined it is usually found to bear no resemblance to the pattern. If the heating be incomplete, and the temperature too low, the action will be somewhat different, but the result will be no more satisfactory. There will be no explosion, but instead the sand in the cope rises and breaks up; the metal at the gate swells and liquid copper continues to ooze out for some time. When examined the casting is found to be full of blow-holes, their number depending on the temperature at which the metal was cast. The effects of overheating or underheating are the same, regardless of the fuel employed—whether coal, coke, oil or gas.

The second requirement is that THE SAND MUST HAVE THE PROPER TEMPER, NEITHER TOO WET NOR TOO DRY.

Experience alone can teach one how best to fulfill this requirement. If copper is poured in green sand the casting will be full of blow-holes. On the other hand, dry sand will not hold together.

THE BRASS FOUNDRY OF THE ELECTRIC CO.—THE MIDDLE AISLE

The foundryman's hardest problem is to produce castings free from blow-holes. Sometimes a casting will look all right on the outside, but blow-holes are found inside when the piece is turned up. Every job requires instructions from the foreman about the temper of the sand, the position of the gate and the risers.

At the Westinghouse Foundry castings are now being made, without difficulty, which range in size from one ounce to five hundred pounds. The difficulties were overcome by observing the following rules:

(1) Heat to exactly the right temperature.

(2) Have the sand at the proper temper.

(3) Melt the copper quickly.

(4) Keep the metal covered at all times.

(5) Never let the metal stand in the furnace when once ready.

(6) Add a small amount of silicon-copper.

COPPER ALLOYS—In mixing and melting brass a few simple rules should be observed:

(1) Weigh carefully.
(2) Melt quickly and uniformly.
(3) Prevent volatization as far as possible.
(4) Pour at exactly the right temperature.

The first rule may seem needless, but bad results are often traceable to careless weighing. Pouring at the proper temperature is of the most importance. At the present time the temperature is estimated by the naked eye, the experience of the melter and skimmer being relied upon to decide when the metal has reached the temperature proper for the alloy and the character of the job to be done.

The use of the pyrometer in the Westinghouse Foundry for the determination of temperature has not been attended with great success, chiefly on account of vibration. In other places the instrument has proven unsatisfactory because of its sluggishness in responding to changes of temperature. The instrument consists of a thermo-electric couple, one element of which is platinum and the other of an alloy of rhodium and platinum, encased in a tube of porcelain clay or plumbago crucible mixture. When the couple is heated a current flows through the junction, and a galvanometer in series with the couple gives a deflection corresponding to the temperature. The casing, however, conducts heat slowly, and some time elapses before the junction of the couple reaches the temperature of the molten mass.

Bearing Metals—A bearing metal high in lead resembling glyco-metal has been made in the Westinghouse Foundry which gives excellent results. It is composed of copper, tin, lead and zinc. This alloy is difficult to make, because of the tendency of the lead, whose specific gravity is high, to settle to the bottom. There seems to be no amalagamation of the lead with the proportions of copper and tin used. To check the precipitation of lead the bottom of the casting was chilled with running water, immediately after pouring. This gave good results with small bearings, but did not with large ones. Finally methods of mechanical mixing were adopted that gave excellent results both in casting and on test. The tests showed remarkably low friction and very small wear.

Another alloy was made up of the same elements, but a different scheme of mixing was adopted. The mixing was divided into two steps: the first constituting of making an alloy low in copper, and the second of mixing this intermediate alloy with copper. The intermediate alloy was made by melting the copper first under a charcoal cover and then adding lead, then zinc, then tin; overheating being carefully avoided. This intermediate alloy was poured into ingot moulds. After cooling, it was put into melted copper. The resultant alloy could be cast in sand and withdrawn while still red hot without showing any signs of lead sweating out, although the temperature of the casting when withdrawn was far above the melting point of lead. The temperature must be watched very carefully, as a slight excess causes the lead to segregate, and, chiefly for this reason, the alloy cannot be made in the Schwartz furnace.

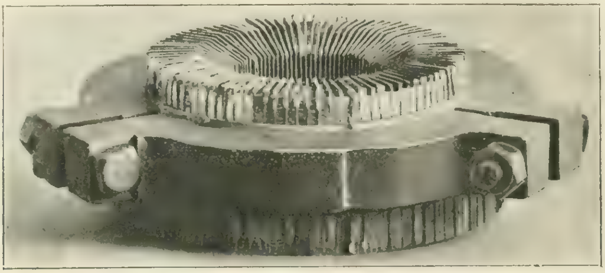
In melting alloys it is customary to melt first the constituent having the highest melting point and then add the others in the order of their melting points, the one with the lowest melting point being added last. Sometimes, however, metals will alloy at a temperature below that of the melting point of some of the constituents; for instance, a brass may be made by first melting zinc, which melts at about 800 degrees F., then taking the crucible out of the fire and adding solid copper, whose melting point is about 2,000 degrees F.

A singular point about alloys containing lead and tin is that lead will separate out if the percentage of tin is considerably in excess of that of lead, but by decreasing the percentage of tin and increasing that of lead, the larger proportion of lead alloys without difficulty.

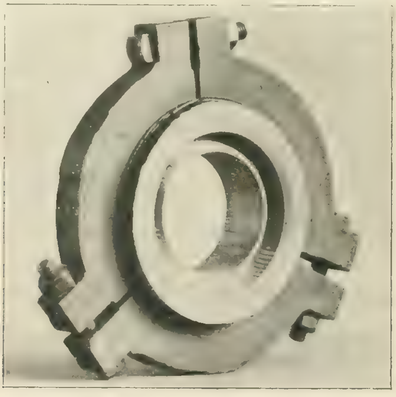
There is an alloy known to the trade as plastic bronze that contains 20 per cent. of lead. This large amount of lead is probably held by a small amount of tin and nickel. The alloy gives very good results.

SAND for cores should be high in silica and low in alumina, bond being obtained with resin, flour and molasses. Sand for moulding should be fine and open. It should not contain much alumina, because the alumina (clay) bakes, preventing the rapid escape of gas, and so causes blow-holes and sponginess.

THE SAND CONVEYOR—In the Westinghouse Foundry, the moulding machines are arranged in two rows, one on either side of the middle aisle. The conveyors, one over each row, carry the sand to spouts, which discharge into the flasks. The operator by opening a gate in the spout allows sand to pour into and fill the placing the segments on end, side by side, in the form of a circle, with the necks at the lower end extending outward, and separating them with the insulating strips allowing the latter to project slightly beyond the copper on all sides. A round iron ring, provided with radially projecting set screws, is placed about the collection of copper and mica and the screws tightened down, thus forcing the segments toward the axis of the commutator as well as nearer together. At this stage the commutator is placed in an oven and subjected to a high heat for some time. The shellac is softened and forced out between the segments as the screws in the binding ring are tightened. This heating rids the commutator of any moisture which may have been in the shellac, but must not be carried far enough to allow the shellac to carbonize, for should this condition exist in a finished commutator, oil, if near the mica insulation, might be absorbed and cause disintegration of the strips.



COMMUTATOR READY FOR BAKING



COMMUTATOR PARTLY MACHINED

After the commutator is removed from the oven and cooled it is machined on both ends, and a dove-tail projection made on each segment, as shown in the photograph. A cast-iron bushing having a projection to fit one of the grooves is placed within the circle of copper bars and a brass ring, having a similar projection to fit the other groove, is clamped to this bushing. On account of the shape of the grooves and projections the segments are drawn together as the brass ring and cast-iron bushing are forced toward one another with bolts. The copper bars are insulated from the bushing and ring by moulded mica insulation, known as mica V rings. When the bars are firmly held together by the inner binding ring the outer one, having the adjustable screws, may be removed and the outer surface machined off.

TESTING ARMATURES FOR SHORT-CIRCUITS—A method of testing for a short-circuited coil in an armature is to provide a laminated iron shoe, much like a field pole in shape and size, which has a form as shown in the figure, such that it will fit closely over a part of the surface of the armature to be tested. Since the face of the shoe has a definite curvature, it can be used only on armatures of certain sizes, but since railway motor armatures do not vary much in diameter, the device is well fitted for this type. The shoe is held in position by an upright support. It carries a coil having several turns of rather large wire, and is supplied with alternating-current pressure at its terminals. The armature to be tested is brought up to the shoe on an armature truck and placed as close as possible. It is then slowly revolved, while an operator passes a small piece of sheet iron over those coils which have part of their winding under the shoe. Since the coils are normally all open there would be no effect produced on the iron sheet if the armature is all right, but should there be a short-circuited coil present having one side under the shoe, alternating currents would be produced in it and the tell-tale would tend to adhere to that part of the armature core lying about its exposed side.

DEVICE FOR TESTING ARMATURES

TESTING COILS FOR SHORT-CIRCUITS—To test coils for a short-circuit a device is used as shown in the sketch. This consists of a laminated iron core with three short legs A, C and B, and co C, M and N, together with the telephone receiver R. The coil has an alternating e.m.f., E, applied to it when testing is to be don which magnetizes the core. M and N are two coils having th

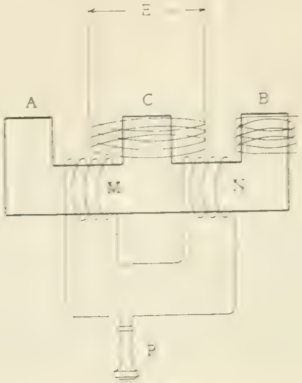


FIG. 1

same number of turns in each, and are placed in the same rel position on the arms with regard to C. They are connected in series with a telephone receiver, but in such a way as to oppose

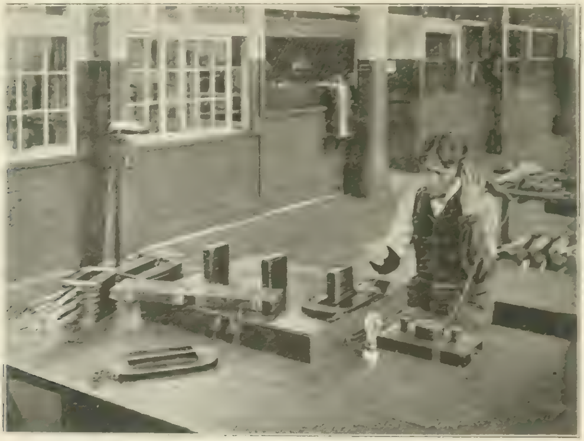


FIG. 2—TESTING A TRANSFORMER COIL FOR SHORT-CIRCUIT

one another. To test a coil as T, place it over the leg B and listen in the receiver. If the coil T is open the same amount of magnetic flux will pass through M and N and no sound will be noticed; but should the coil T contain a short-circuited section, more flux will pass through M and N, and a disturbance in the receiver will result.

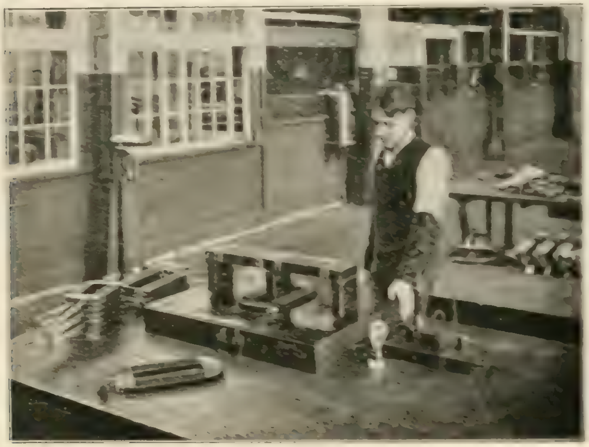


FIG. 3—BURNING OUT A SHORT CIRCUIT

This is illustrated in the photograph Fig. 2. When a short-circuit in a coil is detected it is located by burning out; to do this the coil is placed over the center leg, i. e., in the strongest field, and the field is strengthened by completing the magnetic circuit. This is shown in Fig. 3.

a laminated iron core with three short legs A, C and B, and coils C, M and N, together with the telephone receiver R. The coil C has an alternating e.m.f., E, applied to it when testing is to be done, which magnetizes the core. M and N are two coils having the

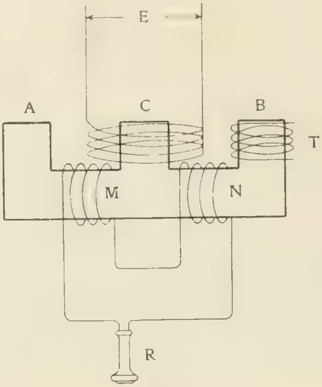


FIG. I

same number of turns in each, and are placed in the same relative position on the arms with regard to C. They are connected in series with a telephone receiver, but in such a way as to oppose

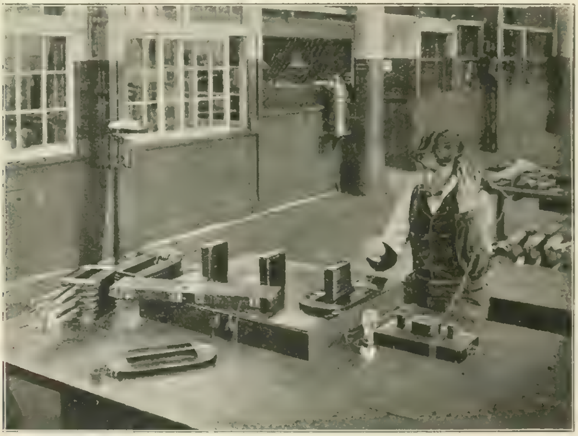


FIG. 2—TESTING A TRANSFORMER COIL FOR SHORT-CIRCUIT

one another. To test a coil as T, place it over the leg B and listen in the receiver. If the coil T is open the same amount of magnetic flux will pass through M and N and no sound will be noticed, but should the coil T contain a short-circuited section, more flux will pass through M and N, and a disturbance in the receiver will result. This is illustrated in the photograph Fig. 2. When a short-circuit in a coil is detected it is located by burning out; to do this the coil is placed over the center leg, i. e., in the strongest field, and the field is strengthened by completing the magnetic circuit. This is shown in Fig. 3.

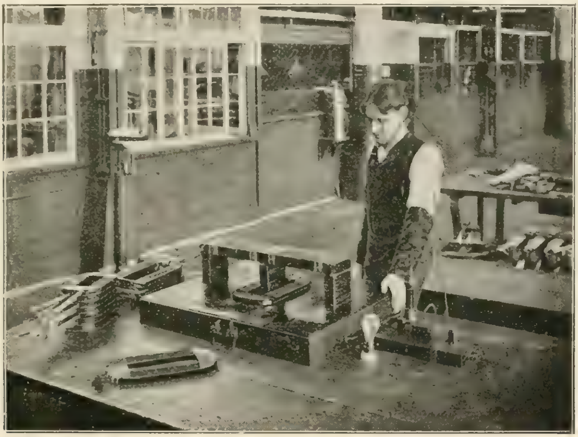


FIG. 3—BURNING OUT A SHORT CIRCUIT

EDITORIAL COMMENT

Mr. Frenyear and Man-Power

One of the things which I have read during the past year which impressed me most was "Man-Power." I did not hear Mr. Frenyear, but I read the manuscript soon after he delivered the address.

First of all, it revealed Frenyear. I had known him for several years. I knew his high character, his excellent habits, his clear logical mind and his definite effective method of presenting his views. But I had not known the depth of his character and the breadth of his mind, nor had I caught the underlying spirit of his life until I read what I recognized at once was not a mere essay, but a statement of his philosophy of life, of what he believed and of the principles upon which his life was based. I had not understood him nor really known him before. Nothing said of him since his death seems to me to be overstated.

The particular thing in the address which I appreciated most is the statement of the true relation which should exist between men in modern society, particularly in a great corporation or industrial works. We have new conditions, new problems. Modern manufacturing, bringing together thousands and tens of thousands of men who must act together as a unit, has led to new products, to new tools, to new methods, and has led to new relations between men. Labor unions, organizations of manufacturers, profit sharing, schemes of arbitration—all these indicate the efforts to fix the new relations between men. Many of these simply propose a remedy for some present evil. But what is the true basis, the basis which is fundamentally right, what is the underlying moral principle upon which alone a secure and lasting solution can be based? As engineers we learned that what is unsound in principle cannot be successful in practice, but must give way sooner or later for something new. "What is the true principle of organization in a democratic community? It is this: Getting others to do what you want done while they are doing what they themselves want to do; inspiring others with a desire to do what you want done, not driving them to do it." This sentence and the notable sentences which follow it give a new significance to the movement toward organization and combination and they set forth a fundamental principle which bears directly upon the most serious problems of the present and the future.

Chas. F. Scott.

Factory Testing

One of the urgent needs of every large manufacturer of electrical appartus is an efficient testing department. This is the department in which everyone who aspires to be an engineer should receive a thorough training, and in which everyone who would have a working knowledge or a personal acquaintance with electrical apparatus should work at least a few months.

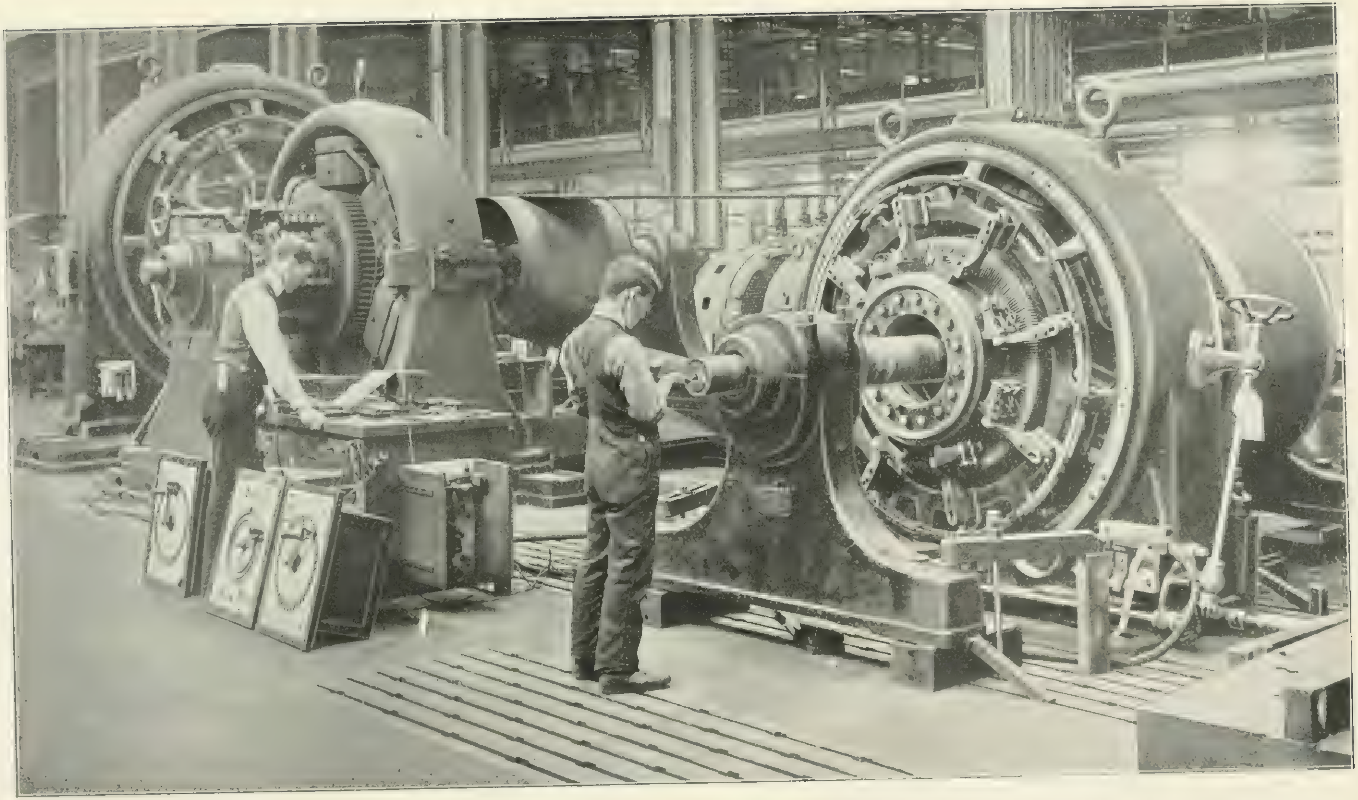
To get the best or even good results for the company the important testing should all be done by experienced men, but owing to the fact that the Testing Department is a preparatory school for the Engineering, Construction, Correspondence and Sales Departments, the force is constantly changing, so that it is almost impossible to have experienced men even in close supervision over the tests For this reason the series of articles on Factory Testing of Electrical Machinery, now appearing in THE JOURNAL, is most timely and deserves the closest attention, especially from those now in the Testing Department and those who hope or expect to get there. The methods in use in the Testing Department are described in detail, and if properly followed the articles should lead to good resuts. It must be understood, however, that all the printed instructions and theoretical knowledge in the world will not make a good tester if he lacks common sense.

It is a source of positive pain to the Engineering Department to observe the frequent lack of this most important faculty; to see, for example, the time that is wasted—absolutely lost—in taking fifteen or twenty readings, each of which requires time, in locating the position of a straight-line curve; to observe the painstaking accuracy, equal to that given by a ten-place table of logarithms, with which an entire series of tests on a machine is made, only to find after all that a field coil is reversed. It is discouraging to have a whole series of tests thrown away because some necessary condition is neglected, to find discrepancies that would have been avoided by anyone but a mere "observer."

To men in the Testing Department we would say, don't be an OBSERVER, be a TESTER. Take a sheet of cross-section paper and plot the readings as taken, so that you may know what you are doing. Work intelligently. In ninety-nine cases out of one hundred the troubles found in the Testing Department can be easily and quickly remedied by the use of one's common sense. It is too frequently the case that some occult reason is sought, and the problem is referred to the engineer, when the real difficulty lies in the mental short-sightedness of the tester. If a machine runs hot, when others apparently exactly like it run cool, there is some good reason for it that can be easily located if it is properly sought for.

A large amount of routine commercial testing is apt to lead to superficial and perfunctory work; but don't let the piece-work system dwarf your honesty and intelligence. Use common sense, and you will soon acquire something which can be bought only by hard work—the experience for which you are looking.

N. W. Storer.



A REGULATION TEST

See Factory Testing of Electrical Machinery, Part III. Page 171

THE

Electric Club Journal

Vol. I. APRIL, 1904. No. 3.

THE INSTALLATION OF ELECTRIC CABLES

By H. W. Buck, Electrical Engineer of the Niagara Falls Power Company.

A lecture delivered before The Electric Club February 29, 1904

I SHOULD like to bring up for your consideration tonight a few general points bearing upon that part of an electric power system which has to do with the distribution of the electric current after it leaves the terminals of the generators. The design and invention in electric generating apparatus which has been in progress for the past ten years has resulted in the development of machines which can almost be considered as perfect in their details of construction, and which will give continuous and satisfactory service for many years without repairs. A great deal of thought has also been devoted to the development of those controlling devices commonly known as "switchboards," and appliances and methods of installation have resulted which can be relied upon to meet satisfactorily almost any condition which may arise in the operation of a plant. There is a tendency, however, noticeable in station design, to confine electrical engineering to these two elements of the plant alone; to consider that if the generators are well built and installed and the switchboard constructed along modern lines, that the success of the power system is assured.

Of equal importance, however, in my opinion, is the design and construction of the cable distribution system, considered as beginning at the terminals of the generators. The details of this part of a plant are too apt to be left until after the station has been completed, upon the assumption that the cables can somehow be run along the wall, through some subway designed for another purpose and through holes which happen to exist here and there in partition walls.

Electric cables themselves have undoubtedly reached a high degree of perfection by many manufacturers, but methods of installing them have scarcely kept pace with progress in other departments of electrical work.

I believe that if statistics were compiled it would be found that more shut-downs of electric power plants were caused by cable trouble than from any other cause—not troubles which could be blamed upon the cable manufacturer for defects in construction, but ones which are directly attributable to dangerous methods of installation. If you will stop in the street of a large city some time and look into a manhole of some electric power system which has been opened up for repairs and observe the hopeless snarl of cables crossing and twisting around each other, you will ask yourself what would become of the customers dependent upon those cables if a good short-circuit should occur in that manhole. If you will look into the crowded cable runways in some power stations where cables of all voltages and classes are bunched together unprotected, you will agree that the matter has not received the engineering thought in design that it should.

In selecting this topic, it was not my intention to try to show you how to install cables under all conditions (for I do not think that the matter has as yet been satisfactorily standardized), but I shall attempt, rather, to point out certain general principles and to suggest directions in which improvements can be made.

Cable installation can essentially be divided into two classes—station wiring and underground wiring, overhead aerial cable work belonging more properly to the subject of power transmission.

STATION WIRING

In laying out the design of a power plant every wire and cable should, if possible, have a definite place provided for it in advance, just as much as for any other piece of machinery. Cables of different classes, that is, cables carrying currents of different voltages and kinds, should, as far as possible, be kept apart from each other. This is a matter of great importance, in order to prevent an interlinking of different systems in case of trouble. I have in mind a case where the secondary leads of a series transformer were bunched together with some small 110 volt direct current switch-operating leads fed from the exciter system. This combination is very common in modern power plants. Through an abnormal rise of voltage on the system the high-voltage primary of this series transformer broke through to the secondary, which in turn struck through to the adjacent 110 volt direct current lead mentioned, and the whole exciter system became charged with high potential, doing considerable damage.

In laying out a power station cable system the questions are often raised whether to use lead-covered or braided cables, and whether to run in ducts or expose upon racks in cable subways. In my opinion, lead-covered cables should not be used in a power house except in places where protection against water is required. The lead sheath being necessarily grounded makes the cable vulnerable to puncture from ground throughout its entire length, which danger does not exist in a braided cable. On account of the softness of lead, it serves as a very poor guard against mechanical injury. If a lead-covered cable is struck the grounded lead is very likely to be driven through the insulation to copper, and the cable is put out of business. Braid-covered rubber cables are not exposed to this risk. As a protection against fire, a lead covering is useless, for the lead melts at a very low temperature, and exposes the inflammable insulating compound to ignition. When once started a lead-covered cable will support its own combustion until completely destroyed.

In high-voltage work a single-conductor lead-covered cable is especially objectionable. Static discharges seem to take place through the insulation to the lead, which rapidly injures the insulation—especially rubber—and a break-down soon follows. I have known a number of instances where such single-conductor cables have withstood a test of three times normal voltage and have broken down at normal voltage a few hours after being put in service. These break-downs occur usually near the ends of the cable. In multiple-conductor cables this action does not seem to occur, the static activity probably being neutralized.

The present tendency in power station construction is to put all cables in groups of ducts as a protection against fire. The arrangement serves this particular purpose, but it is not, in may opinion, a satisfactory solution of the general problem, and it is open to several objections. In the first place, where cables are drawn into ducts a lead sheath is usually needed to protect the insulation from abrasion. If the cable is single-conductor, operating at high voltage, we have the objection stated above against this combination. If the cable is not lead-covered and operates at high voltage, a static discharge also takes place to the tile duct, which breaks down the insulation in time. Furthermore, if the cables in the ducts are of low voltage carrying large currents, and if a number of them are grouped together, serious difficulties will be encountered from lack of ventilation and consequent overheating of the cables.

In my opinion, as a general proposition, especially in high-voltage work, the best way to wire a power house is to use braided rubber insulated wire, supported in free air upon porcelain or other insulators which in themselves have sufficient insulation to withstand the operating voltage of the cable. The rubber insulation then serves only as a safeguard to life in case of momentary contact, and to prevent a short-circuit in case of temporarily placing tools or such things upon the cables. Cables should be spread out as far as possible from each other, in order to obtain the best possible ventilation and to minimize trouble in case of short-circuit.

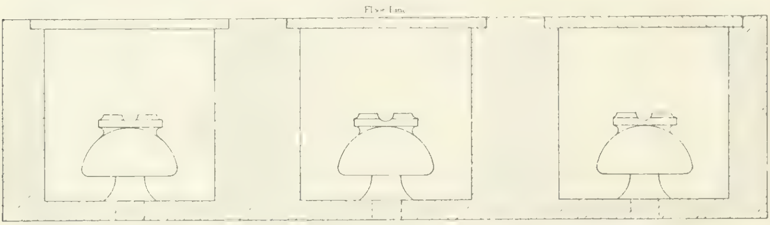


FIG. 1—CABLE RUNWAY FOR STATION WIRING

In connection with the question of ventilation, I should like to call your attention to the fact that the temperature of the outside of a cable does not indicate its maximum temperature. Some experiments made at Niagara by Mr. H. W. Fisher show that there may be a difference as high as 40° C between the outside of the cable and the inside of the insulation. For this reason cables should have their outside temperature kept lower than is ordinarily the case. In laying out a cable system the matter of ventilation should, therefore, be regarded as of prime importance.

Where cables traverse a floor, the arrangement shown in section in Fig. 1 makes a safe installation for cables of even the highest potentials. Where cables or wires pass through walls, the ordinary method of cementing a porcelain bushing in the wall has objections against it. The bushing is apt to crack from differences of temperature on the two sides of the wall, or from settling-strains in the wall, and a break-down occurs. It is much safer to cut a square opening in the wall and place an insulator as shown in Fig. 2. If exposed to the weather, the construction shown in Fig. 3 is simple and is safe for the highest voltages.

Where a large number of cables have to be led through a subway on account of the conformation of power-house structure, they should preferably be racked on insulators in such a way as to give good ventilation and to render each cable accessible. It is well to locate the cables on the walls of the subway and as low down as possible, so as not to be influenced by the hot air which will float at the top of the subway. When cables are installed in this way they should be rendered fireproof by some means. A method which has been adopted by the Niagara Falls Power Company consists of the following:

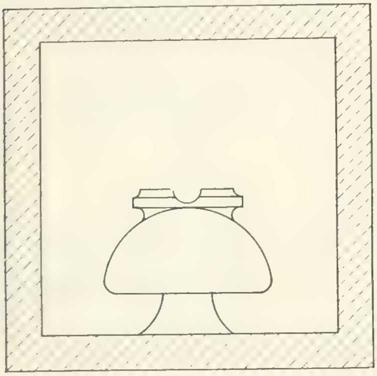


FIG. 2--WALL OPENING FOR LOW-VOLTAGE CABLES

Asbestos strip, about 3 inches wide and $\frac{3}{16}$ inches thick, is soaked in a silicate of soda solution until it is thoroughly impregnated. It is then, while soft, wrapped spirally around each cable which has been put in place on its rack in the subway. This covering very quickly hardens and forms a coating like stone over the braid of the cable which is fireproof. Asbestos applied in this way has many advantages. It needs no binding wire or steel bands to hold it in place around the cable, which are apt to uncoil when most needed, for the silicate serves as a firm bond. Furthermore, the asbestos, having its pores entirely filled, becomes a good conductor of heat, and the heat from the copper losses can get out by conduction. Dry asbestos, on the other hand, in a porous, cloth-like condition, is a good insulator of heat, which is likely to subject the insulation of the cable wrapped with it to a high temperature. The method of fire proofing here described has been given severe fire tests, and it has served its purpose in every case.

Most of the so-called fireproof braids put on cables are not fireproof for this reason: The coiling and uncoiling of completed cable at the factory and during the process of installation cracks the fireproof braid, which naturally is hard and brittle, and leaves it full of minute cracks and pores. As soon as the cable is heated by fire the rubber compound of the insulation gives off a combustible gas which comes out through these cracks and burns in the form of numerous little gas jets, which is practically the equivalent of the rubber burning directly. A wrapping of untreated asbestos strip which is sometimes used is no better, for as soon as the fire reaches the cable so wrapped the heat melts the rubber compound and the asbestos wrapping draws it out like a wick and burns furiously.

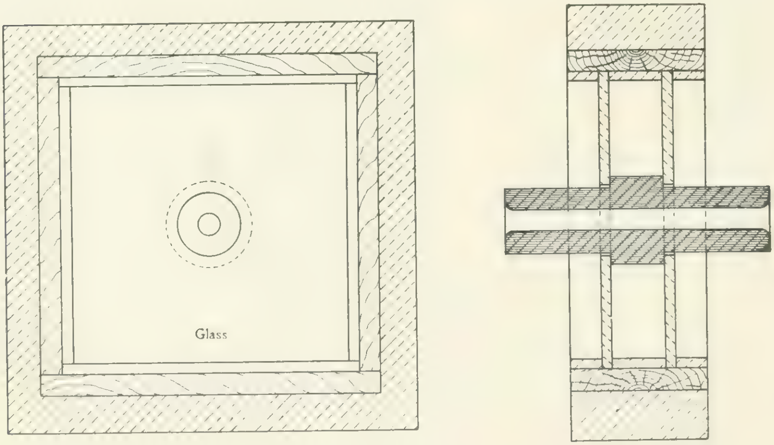


FIG. 3—WALL OPENING FOR HIGH-VOLTAGE CABLES

The covering of impregnated asbestos strip, as described, while hard and brittle also, is not moved after it is put upon the cable, and remains solid and homogeneous, without cracks or pores. This, when heated, confines the melted rubber and inflammable gas and does not carry fire.

Special precautions should be taken in installing the cables in a power house which lie inside of the circuit breakers, for these, in case of trouble, are not protected automatically.

UNDERGROUND WIRING

The conditions governing underground cable work are quite different from interior wiring. Here lead covering is absolutely necessary for cable protection on account of water, and also because paper cables must be used for reasons of economy, and all cables must be drawn into ducts underground, for any form of subway with bracket supports for the cable would be prohibitive in cost.

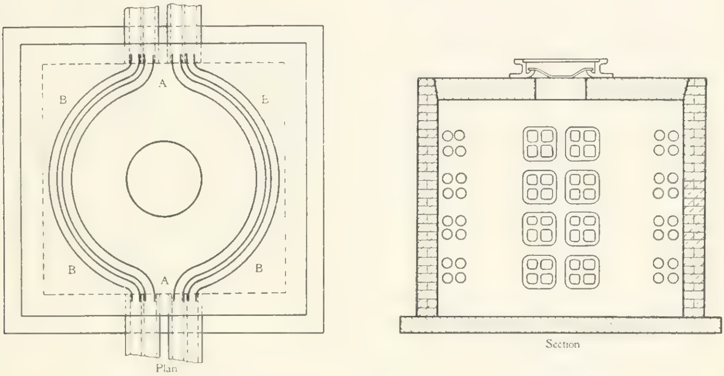


FIG. 4—ORDINARY TYPE OF MANHOLE

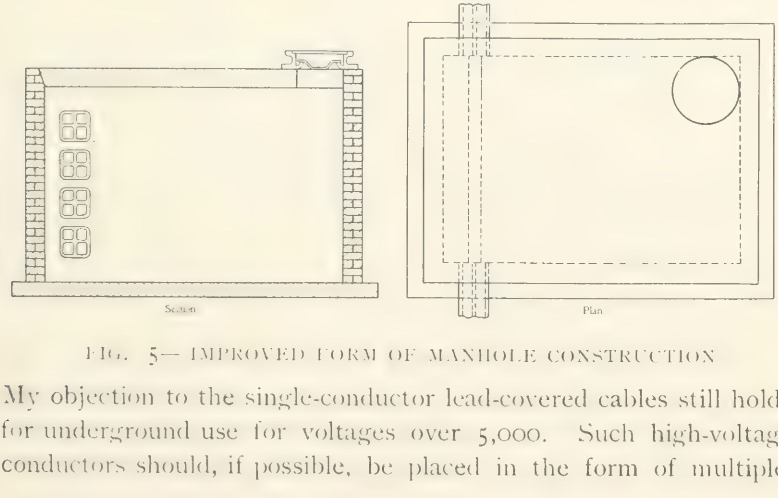


FIG. 5—IMPROVED FORM OF MANHOLE CONSTRUCTION

My objection to the single-conductor lead-covered cables still holds for underground use for voltages over 5,000. Such high-voltage conductors should, if possible, be placed in the form of multiple-conductor cables, where breakdown in insulation from static effects is seldom experienced if liberal sized bells are used at the terminals of the cable.

In connection with underground cable work I should like particularly to call your attention to the grouping of ducts and construction of manholes. Ordinarily ducts are bunched together and brought out at the center of the manhole, as shown in Fig. 4. Here the cables divide, half passing on one side and half on the other side of the manhole, being racked on the manhole walls. This design is objectionable for a number of reasons. First, it exposes every cable in the conduit to damage from short-circuit at the points A-A, where they are in close proximity to each other Secondly, it necessitates bending every cable sharply at points A and B in every manhole, which tends to crack the insulation and

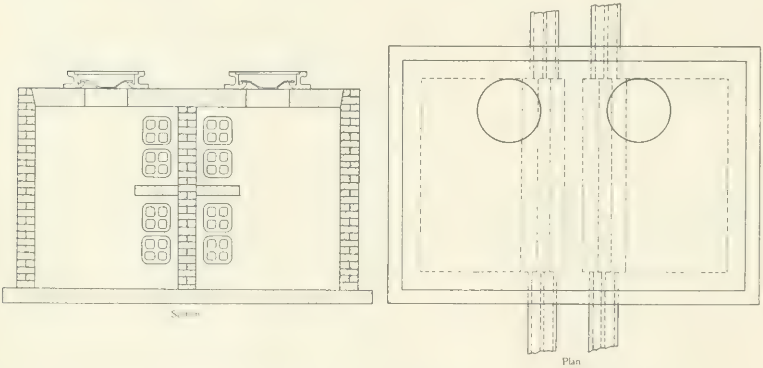


FIG. 6—MANHOLE CONSTRUCTION ADOPTED BY NIAGARA FALLS POWER COMPANY.

cause trouble. Most break-downs in underground work *do* occur at these points. Another objection to this form of conduit construction is from the standpoint of heating. The cables in the inner ducts, if heavily loaded, will rise to a high temperature, for there is no way for the heat to get away by conduction. The inner ducts are surrounded by chambers containing still air, which constitute the best possible insulator of heat.

Ducts, in my opinion, should never be grouped more than two in width, so that every duct will have an outlet for heat conduction through the surrounding earth. A much better form of construction is shown in Fig. 5. Here the ducts are grouped only two in width, and the conduit enters the manhole at the side, so that the cables can pass straight through on the side wall without bending. A further step in design leads to the arrangement shown in Fig. 6. Here the ducts are still laid in one trench, but the ducts are placed in four separate groups, spaced apart by concrete, as shown. The manholes are built with a vertical division wall through the center and two entrance holes. Removable soapstone shelves divide the groups of cables horizontally, so that not more than one-quarter of the number of cables in the conduit can be damaged by short-circuit at any time. In this design the cables also run straight through the manhole without bending. This construction has been adopted by the Niagara Falls Power Company on all its recent conduit work and the results obtained have been very satisfactory in practice. In places where rock is near the surface of the ground the construction shown in Fig. 7 is adopted, which requires only a very shallow excavation and affords excellent conditions for the dissipation of heat from the ducts.

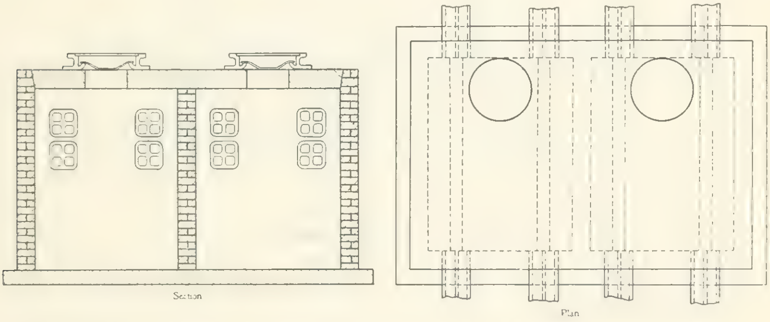


FIG. 7—MANHOLE CONSTRUCTION OF SHALLOW TRENCHES

The heating of underground conduits is a matter which is overlooked to a great extent, and it is probable that many underground cables for this reason are operating at a much higher temperature than they should. The heating constants vary considerably with the nature of the soil surrounding the conduit, but a fairly safe rule is not to exceed 3 watts per duct-foot as a maximum for copper loss in cable, and not to concentrate too many ducts in one group.

The forced ventilation of underground conduits has been tried, but without success. Forcing air under pressure through the ducts has the effect only of lowering the temperature at the end where the air enters, but of raising the temperature toward the end where the air escapes. There is a method, however, of cooling cables in ducts which is very effective, but almost prohibitive in cost, except in a few special cases. It consists of drawing into each duct with the cable a small lead pipe, through which water is kept circulating. This arrangement is used at Niagara in a conduit 250 feet long, between Power House No. 2 and the Transformer House, and the results have been very good.

Where single-conductor lead-covered cables are used in underground installations for carrying large alternating currents at low voltage trouble from induced current in the lead sheath should be guarded against. I do not refer to local eddies, but to the current which flows in the lead sheath of two parallel cables as secondary induced by the current in the copper of the same cables as primary. This secondary circuit is shown in Fig. 8. When the lead circuit is closed at two manholes by contact with supporting iron brackets the current which flows in the lead is very considerable, and the resulting loss is nearly equal to the $I^2 R$ loss in the copper, even at 25 cycles. At higher frequencies this loss will probably be greater. As a specific example I will cite some readings which were taken on two parallel 300-foot lengths of 1,250,000 c.m. cable carrying 800 amperes in the copper at 25 cycles. The open-circuit voltage induced in the lead was 15 volts, and with the lead sheaths short-circuited at one end through an ammeter, the current was found to be approximately 200 amperes. You can see from these figures that the matter is one of the greatest importance, and special precautions should be taken in all underground work to

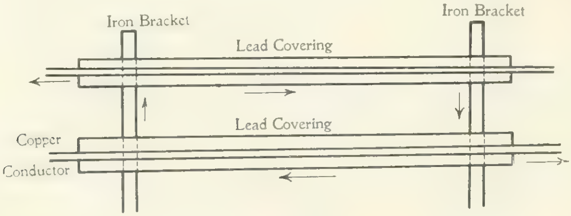


FIG. 8—SECONDARY CIRCUIT FORMED BY LEAD COVERING

meet it. The lead sheaths of all cables should be either bonded together carefully in every manhole or else carefully insulated. If neither one thing nor the other is done, sparking will occur from this lead current at the cable supports at the manholes, which will burn through the lead sheaths and cause a break-down.

In conduits built of insulating material, such as vitrified clay, little trouble need be feared from electrolysis if the conduit is well drained and dry. If the ducts, however, contain water and the cables are partially submerged, the lead covering will rapidly disintegrate, unless the sheath is bonded at frequent intervals to the nearest railway return circuit.

In conclusion I may say that the points brought out in this paper are not based upon theory, but upon actual experience with a large variety of electric cables operating under various conditions.

CAR EQUIPPED WITH SINGLE-PHASE MOTORS

THE WESTINGHOUSE SINGLE-PHASE RAILWAY SYSTEM

By Clarence Renshaw

IN considering the single-phase railway system, it may be divided conveniently into two parts—the generating and distributing system, which includes the generating station, the transmission line, the transformer stations and the trolley line; and the car equipment, which includes the control apparatus, the motors and the auxiliary apparatus. The various details will be described under these two heads.

GENERATING AND DISTRIBUTING SYSTEM

GENERATORS—Two-phase generators are preferable to single-phase on account of the increased output for a given amount of material. The two phases should be kept separate, and should supply different parts of the road. An insulator must, of course, be placed in the trolley wire to separate the two parts of the line thus served.

Where three-phase machines are already installed, they can be utilized by carrying off three separate single-phase circuits, and dividing the line into three sections instead of two.

Frequency—The standard frequency of 3,000 alternations, or 25 cycles, has been adopted for single-phase railway work.

TRANSMISSION VOLTAGE The voltage of the transmission line, which supplies the high-tension side of the transformer stations, may be chosen in the same manner as the voltage of any high-tension transmission line, with reference to the distance of transmission and the general local conditions.

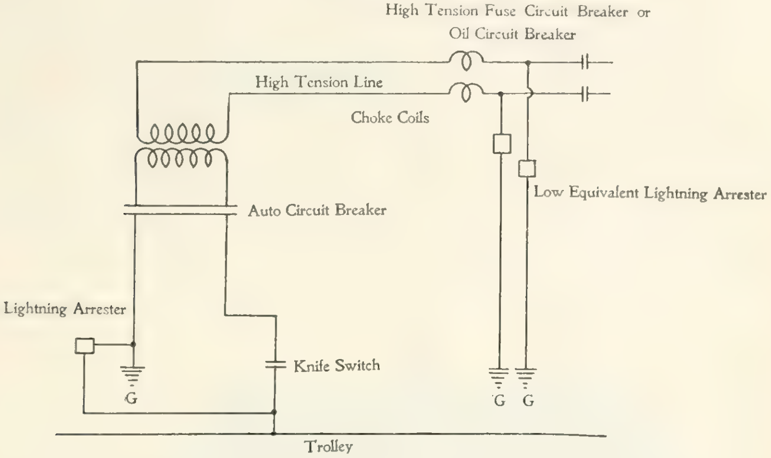

High Tension Fuse Circuit Breaker or Oil Circuit Breaker
High Tension Line
Choke Coils
Low Equivalent Lightning Arrester
Auto Circuit Breaker
Lightning Arrester
Knife Switch
G
G G
Trolley

FIG. I—CONNECTIONS OF APPARATUS IN TRANSFORMER STATION

TRANSFORMER STATIONS—Power will be supplied to the trolley through the transformer stations located along the line. Each station need contain only a single transformer unit, since the stations will be placed so close together that in case of accident to one of them the adjacent ones can supply sufficient power to enable the cars to still operate over the portion of the line ordinarily fed by the damaged transformer station.

In general, with a trolley voltage of 1,000, a car equipment not larger than four 100-hp motors and with a schedule such that no more than two cars will at any one time be located between two adjacent transformer stations, the transformer stations may be placed from about six to eight miles apart without requiring any 1,000-volt conductors other than the trolley wire and the track rails.

There will be no moving machinery in these transformer stations, and therefore constant attendance will be unnecessary. As transformers require only a comparatively small space, the transformer-station buildings may be small and comparatively cheap.

Fig. 1 gives a general idea of the connections of the apparatus in a transformer station containing the following apparatus:

1—Oil-insulated self-cooling transformer.

2—High-tension fuse circuit-breakers, with the necessary barriers.

2—Low-equivalent lightning arresters for protecting the high-tension transmission lines.

2—Choke coils for use with lightning arresters.

1—Automatic oil circuit-breaker in the low-tension circuit between the transformer and the trolley, so arranged as to open only on a continued short-circuit, or a fuse and a switch.

2—Knife switches to disconnect the circuit-breaker from the trolley, to enable inspection or repairs to be made.

1—Low-tension lightning arrester.

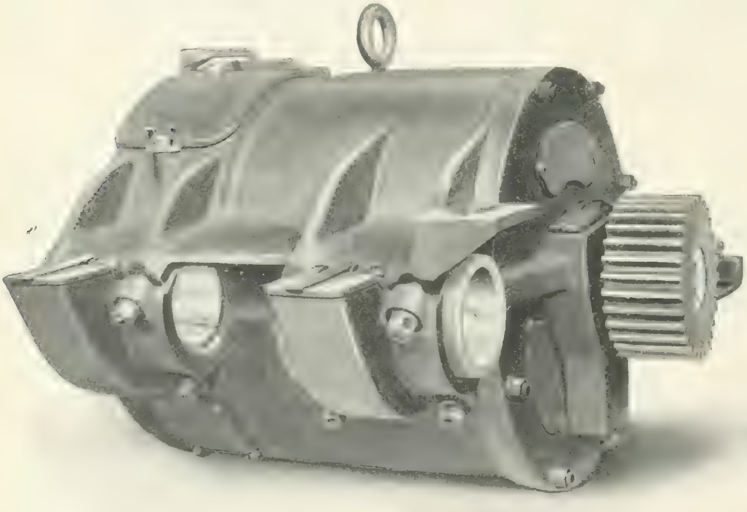


FIG. 2—SINGLE PHASE RAILWAY MOTOR

Trolley Voltage—The voltage which may be used on the trolley is limited in general by the insulating material which is available. A high voltage trolley will require different line material from the present standards. Line material for 1,000 volts can be readily obtained in the market at present, and it is not known that such material for any higher voltage is now on the market. Hence, approximately, 1,000 volts (i. e., 1,100 volts at the generator or transformer station) is, in general, the maximum allowable at present, and this is considered as standard. Lower trolley voltages may be used where local conditions require it.

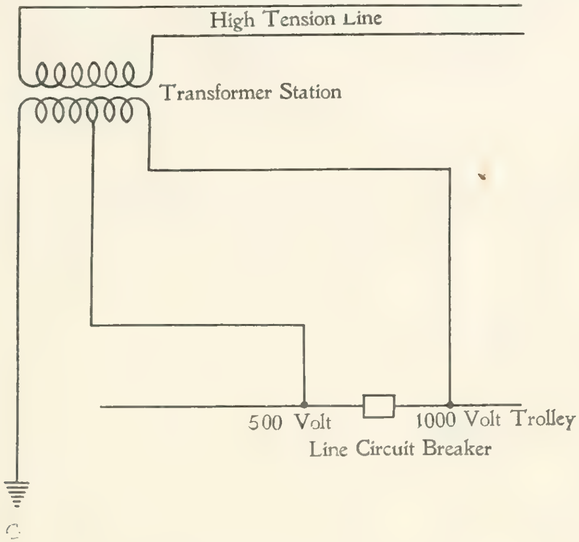


Fig. 3

An equipment can readily be arranged to operate at two different trolley voltages so that, for instance, a high-voltage trolley may be used in open country and a lower-voltage trolley in towns or cities. This arrangement can be provided for by means of a low-voltage tap on the high-tension side of the main auto-transformer on the car, and a double-throw switch, so that the wire from the trolley can be connected to either one of the two taps on the main auto-transformer.

Figs. 3 and 4 show how low-voltage sections of trolley may be supplied. If the low-voltage section is adjacent to a transformer station fed by the

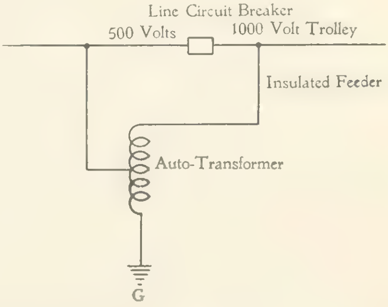


Fig. 4

high-tension transmission line, an extra tap from the low-tension side of the transformer will suffice.

Where it is necessary to pass over tracks already occupied by cars using direct current, an additional trolley wire may be placed alongside of the direct current trolley wire to carry the alternating current. The voltage of this alternating current trolley may then be made approximately the same as that of the direct current trolley.

Should a direct current car place its trolley on the alternating current wire, the inductive resistance of the motors would prevent sufficient current flowing to damage them and the error would be quickly evident from the fact that the car would not operate.

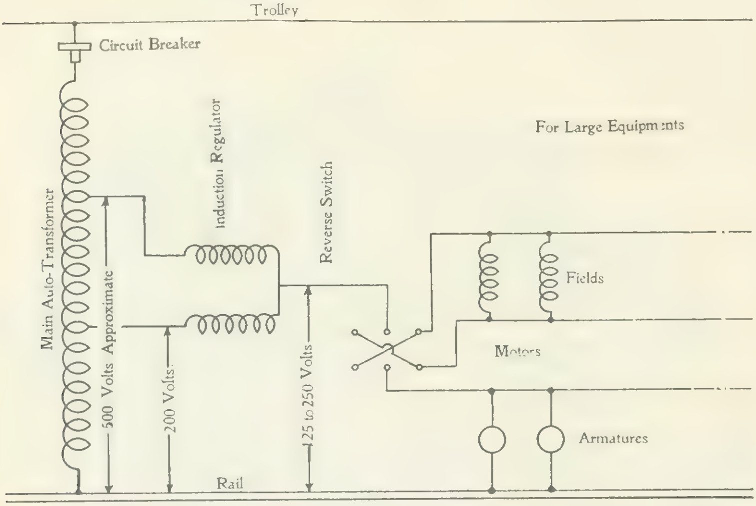


FIG. 5

Should the trolley of an alternating current car be placed on the direct current wire, a large current would instantly tend to flow through the transformer, but this would open the circuit-breaker at once, and damage would thus be prevented.

CAR EQUIPMENTS

The essential details of car equipments are shown in Figs. 5 and 6. Starting from the trolley, these include the circuit-breaker, main auto-transformer, induction regulator (or hand controller), reverse switch, motor cut-out switch, and motors. Lighting transformer, lightning arrester, lamps, sockets, wiring, etc., are also included.

Induction Regulator Control—Any standard equipment for use on cars where compressed air is available, (i. e. cars with air-brakes) can be supplied with induction regulator control. When this is used, the regulator, reverse switch and circuit-breaker will be operated by compressed air from the brake system of the car, and controlled by means of a master switch through electro-mag-

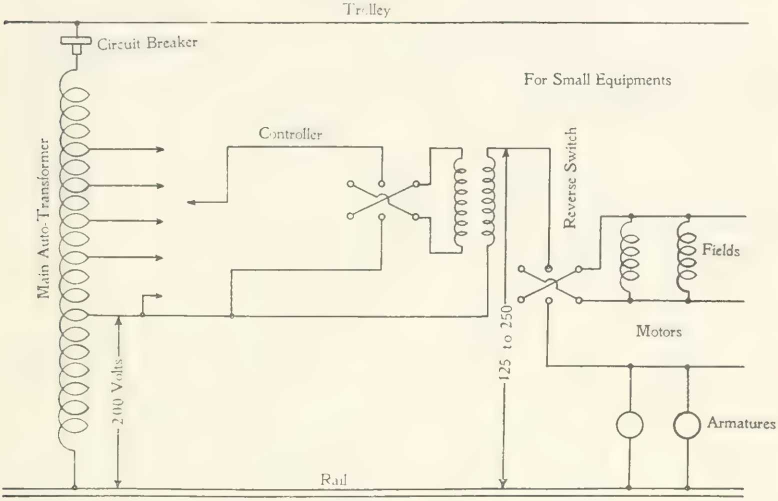


Fig. 6

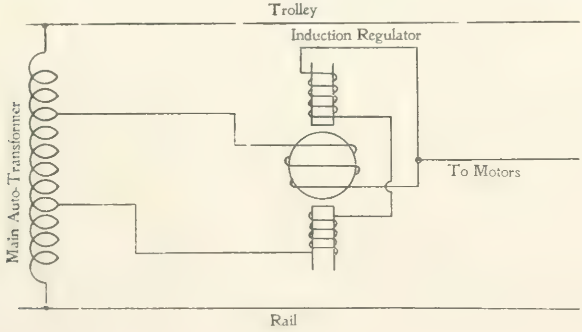


Fig. 7A

netic valves. These valves will be similar in general, to those used on direct current unit-switch control and on the signaling systems of various railroads.

Action of Induction Regulator—The action of the induction regulator may be easily understood by reference to Figs. 7A and 7B. The regulator is essentially a transformer with the primary core and winding movable with respect to the secondary.

With the primary as in Fig. 7A, the maximum voltage is generated in the secondary of the regulator, and it opposes the voltage of the main auto-transformer. With the primary 180 degrees from this position, the voltage of the regulator will aid that of the auto-transformer. With the primary of the regulator in the position shown by Fig. 7B, the voltage of the secondary is zero, so that it neither aids nor opposes the voltage of the auto-transformer.

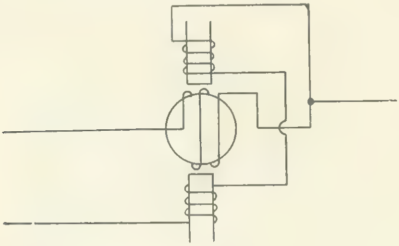


FIG. 7B

The car is started with the voltage of the regulator a maximum, and opposing that of the auto-transformer. The regulator is then moved gradually until the position is reached where its voltage is a maximum and aids that of the auto-transformer. This is then the full-speed position.

Train Control—The induction regulator control can be readily adapted for multiple-unit train operation with slight additions in the way of apparatus and wiring.

HAND CONTROL—For small equipments hand control may be used. This will consist of platform controllers similar in general to the present direct current controllers.

With the hand control, as now proposed, the motors will be connected successively to different taps on the main auto-transformer, as shown in Fig. 5. The voltage applied to the motor thus depends on the position of the contact point *D*. This control will have a definite number of steps similar to the direct current control but the motors can be run continuously on any step, and there will be no rheostatic losses.

MOTOR VOLTAGE—As may be seen from Figs. 5 and 6, the motor voltage is entirely independent of the trolley voltage. A standard motor voltage of 250 has been adopted for single-phase railway motors, regardless of the trolley voltage used.

LIGHTS AND AIR COMPRESSOR—In general, the lights in the car will be supplied by a small auxiliary transformer reducing the trolley voltage to approximately 50 volts. If electric heaters are desired, these may be operated from the main auto-transformer. The air compressor for supplying brakes and operating the induction regulator will be operated by a series alternating current motor taking current from the lighting transformer.

ARRANGEMENT OF MOTORS—As a rule, the motors will be connected permanently in parallel, both in two and four-motor equipments. The use of voltage control makes series-parallel connections unnecessary and inadvisable.

The fields of all of the motors will also be connected permanently in parallel, substantialy as shown in Figs. 5 and 6, thus allowing a simple reverse switch. Such an arrangement is permissible with alternating current, although not with direct current since with the former the currents automatically adjust themselves to give equal field strength in each motor.

WEIGHTS OF EQUIPMENTS—In general the motors will weigh approximately the same as direct current motors of the same capacity. In general also the regulator and transformer for a four-motor equipment will together weigh approximately the same as a single motor.

A complete equipment including all apparatus will weigh approximately 15 percent more than a direct current equipment of the same capacity.

Since the weight of an equipment usually forms only about one-fourth of the total weight of car, equipment, and load, however, an alternating current car should in general exceed the weight of a direct current car by less than 5 percent.

TROLLEYS—For single cars run at speeds not over 60 miles an hour and with trolley voltage of approximately 1,000 it is proposed at present to use standard direct current trolleys, except that an insulating base will be provided. Protection in handling the trolley rope will be afforded by insulators between the rope and the trolley, and by having a grounded metallic end on the part of the rope which is handled.

For very high speeds, or where cars are to be run in trains at all times, a form of bow-trolley will be used.

MOTORS—Motors of 50, 75, 100 and 150-hp are being built, and are considered standard sizes.

In general, the external appearance of the motors will be similar to that of direct current motors. The construction, however, will be slightly different. The entire magnetic part of the field will be laminated, the field being built up of annular punchings, with poles projecting radially inward.

The punchings will be held together in a steel frame. The motor will thus be of the box type, the armature being put in or taken out through the ends.

The field coils will be of copper strap of large cross section, and there will be but few turns per coil.

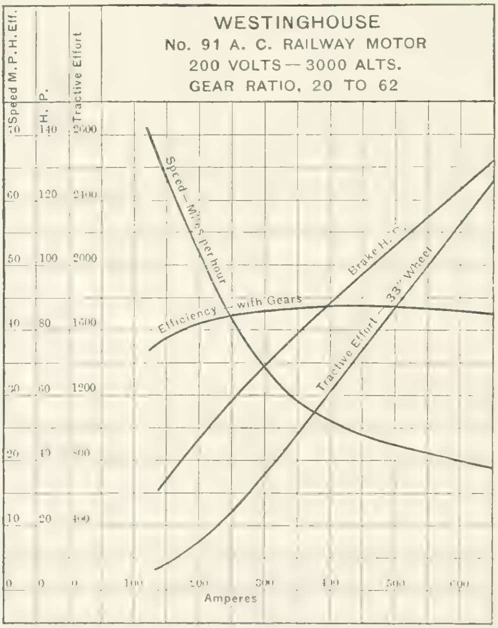


FIG. 8.

The armatures will, in general, be similar in all essentials to the armatures of direct current railway motors.

The illustrations and curves of the No. 91 railway motor herewith given represent the first commercial design of these single-phase motors. Motors now being built will have substantially the same appearance as the No. 91 motor, but will represent an advance both in performance and in mechanical design.

Capacity—The horse-power ratings which are given to these motors correspond, in general, to the nominal horse-power ratings which are given to direct current railway motors. That is, it is the load which the motors will carry at rated voltage for one hour with a rise in temperature of approximately 75° C in the windings. The temperature is measrued by thermometers.

In general, these motors will carry continuously from 45 to 50 percent of their full load current at the reduced average voltage which would be placed upon them in actual service, with a rise in temperature of approximately 60°C.

As the armature may be momentarily short-circuited without damage to the motor, there should be no tendency to flash across between brushes, or from the brushes to the frame of the motor.

POWER-FACTOR—The apparent input of an alternating current motor may be divided into two components at right angles to each other. One of these is called the energy component and the other the inductive component. The energy component represents the power input to the motor, and includes not only the useful input which appears as output at the shaft of the motor, but also the losses. The relation between these two components is such that the sum of their squares is equal to the square of the total apparent input.

The power-factor of a motor is the ratio of the energy component to the total apparent input, and since it is merely the ratio of two quantities, the power-factor alone gives no idea of the value of either quantity. In judging whether the performance of a given motor is good or bad, a knowledge of the power-factor alone is thus of little value. The important considerations in any given case are the actual magnitudes of the energy and the inductive components and the proportion of the former which represents useful energy, and in order to determine this, further information is necessary. If the apparent input, for instance, is known in addition to the power-factor, then the value of the energy and inductive components can be readily found. If the efficiency is also known, the useful energy may then be found from the total energy.

Many engineers hold the idea that high power-factor in a motor is desirable under all circumstances, just as a high efficiency is desirable, this idea is mistaken and misleading.

The effects which are ordinarily attributed to a low power-factor are really due to a large inductive component. If the value of this inductive component is kept the same for any given output, and the power factor raised by increasing the energy component, the general conditions will be worse rather than better. If two motors, for instance, have the same inductive component with a given output, but the efficiency of the first is less than that of the second, then the energy component of the first will be greater than that of the second, and consequently the power-factor of the first will be greater than that of the second. In this case the motor with the higher power-factor is the poorer of the two, since it has the same inductive element and at the same time requires a greater actual power input.

In the alternating-current railway motor the inductive component depends on the current. Since approximately the same current is required to produce a given torque, whether the motor is merely at the point of starting or whether it is running at full speed, the inductive component will be practically the same for a given torque whether the motor is starting or whether it is running at full speed. When the motor is running at full speed, however, there is a large output, and consequently a large energy component, thus giving a high power-factor. At the moment of starting, there is no output, and the only energy component in the motor is that due to its losses. If the internal losses are low (which will be the case with an efficient motor), then the power factor of the motor when starting will also be low.

Since the alternating current railway motor has a high power-factor at full load (approximately 90 percent or more), it is evident that the value of the inductive component under these circumstances must be relatively small. It has already been noted that when the motor is starting with full-load torque the inductive component is the same as at full load. Since there is no power developed when starting (due to the fact that the speed is zero), the only energy component which there can be is that due to the losses. A motor of low efficiency, therefore, would show a fairly high power-factor under these circumstances, since it would have a fairly large energy component. The fact that the power-factor under these circumstances is not high, thus shows that the losses are not high: that is, that the motor is an efficient one.

In considering the matter of power-factor when starting, the alternating current railway motor must be carefully distinguished from the induction motor. In an induction motor, to produce full-load torque at the start, there must be an expenditure of full-load energy in the secondary circuit, and for other starting torques a proportionate amount of energy is required. In an induction motor, therefore, the energy component at starting is in general taken as an indication of the torque, although a large expenditure of energy does not necessarily mean a large torque.

In induction motors, as in all alternating current motors, it is desirable to keep the inductive component as small as possible, and since a large energy component is necessary to produce a large torque at starting, a high power-factor when starting with large torque is in general taken to mean a low inductive component, and consequently a favorable condition. A high power-factor at the

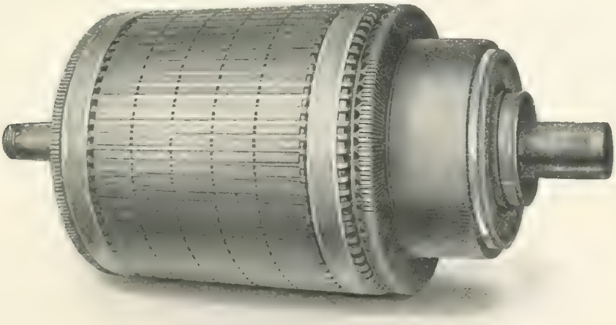


FIG. 9—SINGLE PHASE RAILWAY MOTOR ARMATURE

start in an induction motor, however, does not necessarily mean a low inductive component, and hence does not necessarily mean a favorable condition.

In starting any alternating current motor, it is impossible to avoid the presence of an inductive component. In starting an induction motor, however, an energy component proportionate to the torque developed is also required in addition to this inductive component. In the alternating current railway motor, however, the torque developed depends on current only, and the development of a given torque does not require the expenditure of any given amount of energy. The inductive component or wattless current has the same effect in producing torque as an energy current of the same amount. In the alternating current railway motor, therefore, since the inductive component will be present in any case, it is desirable to utilize this current for producing as much of the necessary torque as possible, thus keeping the energy current (and the energy) for a given torque as small as possible. That is *with a given inductive component it is desirable to reduce the power-factor at starting to as low a value as possible*, since this means that the losses will then have as low a value as possible.

The fact that a low power-factor at starting represents an advantageous condition rather than a disadvantageous one with the alternating current railway motor, may be seen in another way. In order to produce a given torque, a certain current is necessary. With a direct current car, practically the same current per motor would be required to produce a given torque, as with an alternating current car, provided the conditions of gear ratio, etc., are the same. In the direct current car, however, the product of the current and volts would represent the energy taken from the circuit. In the alternating current car the product of current and volts would be approximately the same as that for the direct current car, but this product would represent only apparent energy and not real energy. Since the power-factor in the case of the alternating current car would be low, usually from about 30 to 40 percent, the real energy supplied to the alternating current car would be only this percentage of that supplied to the direct current car for producing the same torque.

There has been a tendency on the part of engineers who have not fully understood this point to critize the fact that the alternating current railway motor has a low power-factor when starting. It will be seen from the above, however, that this low power-factor when starting represents a favorable condition instead of an unfavorable one. It is evident that a certain current is necessary to produce a good starting torque, and if this current can be obtained without a corresponding expenditure of energy, so much the better.

COMPARISON WITH DIRECT CURRENT SYSTEM

The operation of direct current railway systems has been eminently satisfactory for two main reasons: First, because the direct current series motor, owing to its variable field, has speed torque characteristics which make it particularly suitable for traction work, and second, because only a single trolley is necessary. The direct current railway system has, however, a number of disadvantages, the most serious of which, perhaps, is the comparatively low trolley voltage which is necessary. This feature has hampered to a considerable extent the development of such roads.

Owing to the ease and economy of voltage transformation with alternating current, the use of alternating current motors would permit a high trolley voltage and at the same time a low voltage at the motors, since a transformer could readily be placed on the car to reduce the trolley voltage for use at the motors. Until recently, however, the only alternating current motors which were available were of the polyphase induction type, and such motors, in addition to not having the proper characteristics for railway work, had the further disadvantage of requiring at least two trolley wires.

The alternating current railway system which the Westinghouse company has recently placed on the market possesses the two main advantages of the direct current system, since the motor which is used has the same speed-torque characteristics as the direct current series motor, and since single-phase circuits obviously require only one trolley. In addition to possessing these two main advantages of the direct current system, this alternating current system overcomes a number of its limitations. This is best shown by the statements in parallel columns, which follow:

DIRECT CURRENT SYSTEM	ALTERNATING CURRENT SYSTEM
(1) The voltage of a direct current circuit can be changed only by the use of rotating	(1) The ideal arrangement of high-trolley voltage, giving economy of transmission, and

machinery. It is thus, in general, necessary to utilize power at approximately the same voltage at which it is generated. A high voltage is desirable for transmitting power, in order that the currents necessary for a given output may be small. On the other hand, the voltage for which motors of the commutator type can be made is limited. A voltage of nominally 500, but actually as high as 600, has been adopted as the standard for direct current railway work. This is a compromise—being low from the transmission standpoint and high as regards the use of commutator type motors.

(2) Power can be transmitted with reasonable economy by direct current at nominally 500 volts for from five to ten miles from the generating station. For greater distances than this the cost of conductors becomes excessive. A long-distance railway would thus require power stations located from ten to twenty miles apart.

To overcome this difficulty, power is often generated as alternating current and transmitted at high voltage. It is then changed into direct current by means of lowering transformers and rotary converters located in sub-stations at suitable intervals along the road. In these systems the cost of installation and maintenance of a sub-station is such that their use may be looked upon as a method of making long-distance railways possible, rather than as a means of reducing the cost of direct current feeders.

(3) Variable voltage for starting and regulating the speed of the motors is obtained by connecting the motors in series or parallel, thus obtaining two economical speeds. Additional speeds are obtained by the use of a rheostat in connection with both of these combinations. As ordinarily installed, the capacity of the rheostat is such that it may be left in circuit for only a very short time, so that, except momentarily, only two speeds (i.e., series and parallel) are available for continuous running with a given torque.

(4) The motors are connected in series or in parallel and to the various resistance steps by means of a controller, which, in general, consists of a number of contacts bearing on a revolving drum. The circuit is partially opened whenever the connection is changed from one resistance step to another; and in changing from series to parallel, or in cutting off the power, the circuit is completely opened. A powerful magnetic blowout is used to break the arc which is formed on opening the circuit, and thus prevent burning of the contacts.

low motor voltage, giving minimum motor trouble, can be obtained by means of a transformer on the car.

(2) Long-distance roads can be supplied by means of transformer stations, instead of rotary converter sub-stations. These will be comparatively cheap, will contain no synchronous or moving machinery, and will consequently not require constant attendance.

The omission of synchronous machinery renders the service less liable to interruption, since momentary short-circuits, or similar troubles, which might interrupt the service where synchronous apparatus were used, would in many cases cause no interruption in a system where such apparatus was not used. Moreover, in case of a shut-down from any cause, service on a system without synchronous apparatus can be resumed much more quickly than in the case of one in which it is necessary to synchronize a number of rotary converters before power can be put on the line.

Although the rotary converter is a highly efficient machine, some losses necessarily take place in it, especially where it is operated with a low load-factor. The omission of rotary converters, and their consequent losses, should thus add materially to the general efficiency of the power system.

A trolley voltage much higher than is at present in use is allowable with alternating current railway motors, supplied by means of a transformer on the car, and this, combined with the cheapness of transformer stations, will, in general, allow the latter to be placed sufficiently near each other to render any feeders other than the trolley wire unnecessary. These stations will, in general, not require to be placed much closer together than would rotary converter sub-stations.

(3) Owing to the ease and economy of voltage transformation with alternating current, any desired voltage may be applied to the motors without the use of resistance. Motors may thus be run continuously at full speed, or at any lower speed, and the power consumption at all speeds will be proportional to the energy actually expended in driving the car.

(4) Instead of a controller making and breaking a circuit on each step, the motors (in all equipments except those of small size) will be controlled by means of an induction regulator, simple and substantial in construction, and without make and break contacts or similar wearing parts. In changing from one voltage to another, this change is produced gradually instead of by definite steps, as in the direct current system.

(5) When starting a car the rheostatic loss is large, since almost the entire voltage of the line is taken up in the rheostat.	(5) Since there are no rheostats, there will be no rheostatic loss.
(6) The use of direct current on grounded circuits is always attended by electrolysis.	(6) With the use of alternating current instead of direct current, electrolysis will practically disappear.

In concluding this description of the various features of the single phase railway system, and its advantages as compared with the present direct current system, it should be borne in mind that the advantages accuring from this system are due primarily to the use of alternating current, rather than to any advantages of the alternating current railway motor over the direct current railway motor. It is, in general, sufficient praise for the alternating current railway motor to say that it weighs no more than the direct current motor, that it has equally good characteristics, and that it is almost as efficient. The credit for the entire advantage gained, however, must be given to the alternating current railway motor, since it is the development of this motor which has made the exclusive use of single-phase alternating current on railway systems practicable.

A TEST FOR INDUCTION MOTOR WINDINGS

By G. H. Garcelon

THE standard winding for an induction motor primary is shown in detail in the photograph Fig. 1. The winding may be considered as made up of units or "groups." The coils of one phase for one pole compose a group, the number of groups in a winding being equal to the number of poles multiplied by the number of phases.

The different coils in each group are all connected in series, so that current flows through them in the same direction, by means of short connectors between the coils, called "stubs"; the group is very similar to the field coil of a direct-current motor, except that the different turns are *distributed* in several slots. The different

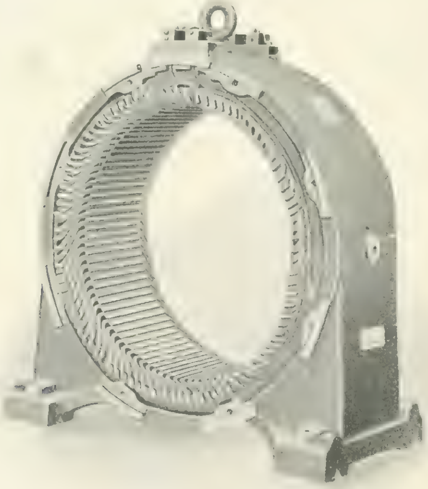


FIG. 1 INDUCTION MOTOR PRIMARY

groups of each phase are connected together, so that current passes through alternate groups in opposite directions, thus producing alternate north and south poles; they may be connected all in series or in equal parallel circuits, depending principally upon the voltage at which the motor is to operate. There can be as many circuits in parallel as there are poles.

In a three-phase winding, the phases are connected together, one end of each phase being brought to a common connection and the other three ends serving as the terminals of the motor. In a two-phase winding, the phases are usually separate, all four ends being brought out as terminals.

The connections of a three-phase, four-pole winding are shown in Fig. 2, each coil representing a group. By following out the winding, it will be seen that one end of each phase is brought to the common connection, *Y*, the other three ends forming the terminals of the winding; it will also be seen that the phase *B* is connected in the reverse direction from phases *A* and *C*. This is the form of connection used in practically all three-phase induction motor primaries and is called the *Y* or "star" connection.

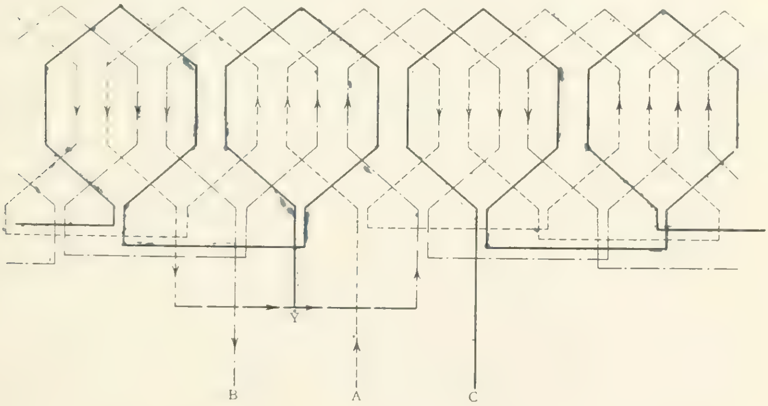


FIG. 2—THREE-PHASE INDUCTION MOTOR WINDING

Fig. 3 is a diagram of connections for a two-phase, four-pole winding. The phases are entirely separate and the winding is simply two single-phase windings. Therefore it is much simpler to connect and test than a three-phase winding.

The winding errors which occur are wrong connections between groups, resulting in a reversed group or even a reversed phase; the accidental use of wrong coils, usually coils having a wrong number of turns; short-circuits in the coils; or open-circuits in the coils. Mistakes arising from wrong cross-connections rarely get past the winding inspector, as they are easily detected by an inspection of the winding. The common errors which develop in the winding test are the hidden ones—short-circuits, open-circuits, and wrong coils—which can only be detected electrically.

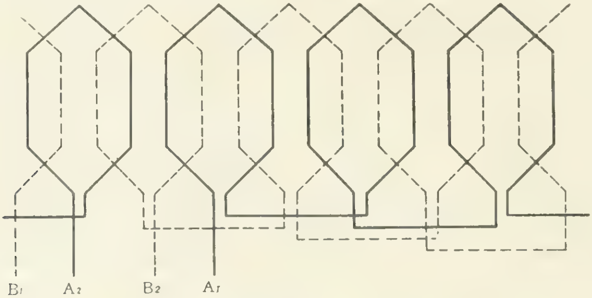


FIG. 3—TWO-PHASE INDUCTION MOTOR WINDING

A test employing direct current might be used; the effect, however, of some of the common faults, a short-circuited coil, for example, upon the ohmic drop is so small that defective motors would often be passed. By using alternating current, not only is the ohmic drop effected by errors, but also the inductance, thus magnifying the defects. The higher frequencies are of course used, as a larger impedance drop can be obtained with the same current flowing.

The test is based upon the fact that any error in the winding will destroy the symmetry of the magnetic field produced by the winding when single-phase alternating-current is passed through it. This, in turn, will effect the impedance of the winding. The test may be best described in connection with a three-phase winding; the application to a two-phase winding will be obvious. Referring to Fig. 2, suppose the terminals *A* and *B* to be connected to a single-phase alternating current circuit, current will flow through phase *A* to the common point *Y*, thence through phase *B* back to the line. The arrows designate the instantaneous direction of the current.

From this it is seen that the current in phase *A* is flowing in the same direction as that in phase *B*, where the conductors of the two phases are adjacent. Therefore the two phases are assisting each other in magnetizing the core. If the current was applied to *A* and *C* or to *B* and *C* the same affect would be produced.

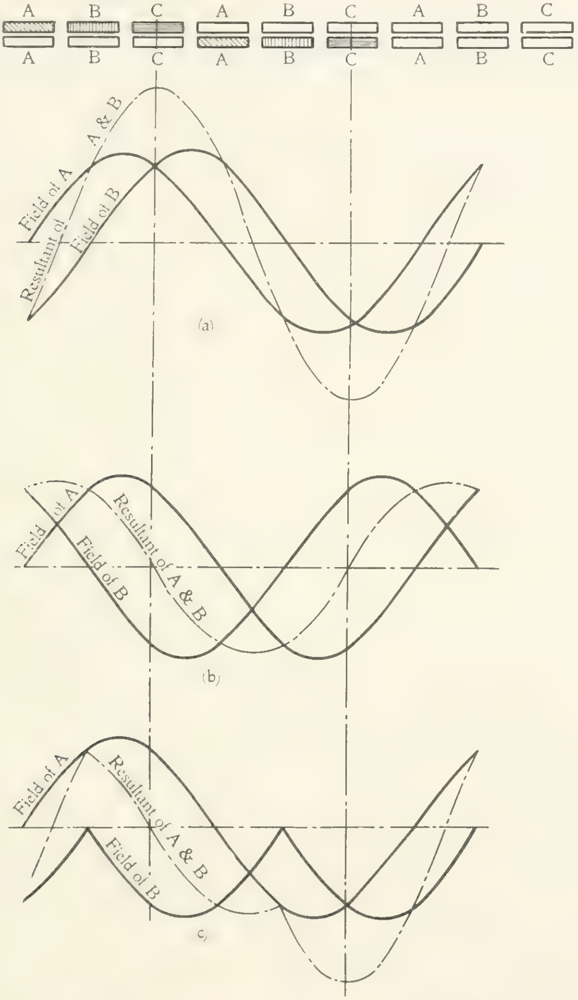


FIG. 4 INDUCTION MOTOR FIELD FORMS

The rectangles at the top of Fig. 4 represent the developed cross-section of the winding. The two rectangles similarly crosshatched represent the two sides of the coils of the same group. The field due to the group *A* will be between A and A with a maximum half-way between. Similarly the field due to the group *B* will be between B and B and have its maximum at the center. Since the current is in the same direction in the adjacent conductors of each group the fields will also be in the same direction. Assuming theoretical field-forms and plotting in the positions just noted, we obtain from them the resultant field-form from the correct winding, shown at (*a*) of Fig. 4. Any mistake in the winding will affect the symmetry or position of the resultant field-form. Suppose, for example, phase *B* be reversed. Then the field due to each group of that phase would be reversed. Fig. 4 (*b*) shows the field-form of *B* reversed, also the resultant of *A* and reversed *B*. The form and position of the resultant are changed. If one group of phase *B* is reversed the field due to that group will be reversed, while those of the other groups remain unchanged. This will cause a distorted resultant field at the pole containing the reversed group. The distorted field-form due to such an error is shown at (*c*) of Fig. 4. The smaller errors, short-circuits, etc., affect the symmetry of the field in a similar way, but to a smaller extent. It may be of interest to note that the different field-forms shown in Fig. 4 have been verified experimentally by means of an exploring coil.

Any change in the amount or distribution of the magnetic flux produced by the winding means a corresponding change in the self-induction and practically the same change in the impedance of the winding. This fact is the basis of the first test made on the winding when it comes to the tester—to determine whether or not the winding is correct.

This is done by observing the impedance drop across each phase in the following manner:

Single-phase alternating current is applied at any two terminals of the three-phase motor. This, as we have seen, will cause a flow of current through the two phases connected, and will produce symmetrical fields at each pole, as shown in Fig 4 (*a*). Since each phase is of the same number of turns, is similarly wound and carries the same current, the impedance drop across each will be the same, if the winding is correct. Also, if the winding is correct, the phase whose free terminal is not connected to the supply circuit is so situated with respect to the magnetic field produced by the other two phases that there is no e.m.f. induced in it, in other words, it acts simply as a potential connection to the common point of the three phases. The coils of phase *C* embrace equal positive and negative parts, of the resultant field produced by *A* and *B*, as shown by Fig. 4 (*a*).

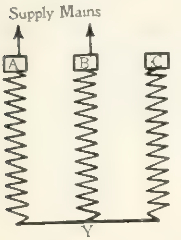


FIG. 5—INDUCTION MOTOR WINDING

Fig 5 shows the circuit diagrammatically, *A* and *B* connected to the supply circuit and *C* free.

By changing the supply mains to *A* and *C*, then to *B* and *C*, and taking voltage readings, all the phases are verified. A set of readings similar to the following would result, any variation showing an error of some sort in the winding:

Current Applied to:	*Amperes*	*Volts*		
		A—B	*B—C*	*A—C*
A—B	14.7	70	35	35
B—C	14.7	35	70	35
A—C	14.7	35	35	70

If these readings indicate an error, then the second part of the test—the location of the error—must be made. It has been pointed out that the field forms should be symmetrical for a correct winding. If the winding is faulty, irregularities will exist in the form of the field at the points where the fault is located. The field form may be obtained by moving an exploring coil around the core. A simpler way is to measure the drop from stub to stub, the stubs being easily exposed by removing the tape. These drops should be alike for each coil symmetrically located with respect to the poles. The reading which varies locates the error in the coil between the stubs giving it. This procedure is necessary to locate the common faults, but it will be interesting to see how such mistakes as a reversed phase or a reversed group affect the first part of the test and locate themselves at once without an application of the second or locating test.

Let us suppose phase *B* to be reversed, and current fed to *A* and *B*. The voltage readings would of course be *A—C* and

B—*C*, which should be equal. However, the phase *C* is not idle in this case, but embraces the entire resultant field of *A* and *B*, as shown in Fig. 4 (*b*). The electromotive force induced in *C* is approximately equal to one-half the impressed voltage *A*—*B*, because the resultant field is nearly equal to that of either *A* or *B* alone. This will make the voltage *A*—*C* approximately equal to *A*—*B*, the impressed voltage. The voltage *B*—*C* will be zero, or nearly so, since the electromotive forces *B* and *C* are opposed and nearly equal. With current in *B* and *C* the readings will be similar, while with current in *A* and *C* they will be normal, since the reversed phase is then inactive. The readings are given below. In this and all following examples the small letter indicates the defective phase.

Current Applied	*Amperes*	*Volts* *A—B*	*B—C*	*A—C*
A—b	31.2	70	0	70
b—C	31.2	0	70	70
A—C	14.7	35	35	70

The results when a group is reversed are similar, although less marked.

If a coil is connected with the wrong group, the voltage of one phase will be high while that of another will be low, since, if the coil is not in the right group, it must be in an adjacent group, and consequently in another phase. This mistake is easily located by counting the stubs in each group, and, therefore, rarely reaches the winding test.

One or more short-circuited coils will lower the impedance of the phase containing them, owing to the decreased inductance caused by the induced current in the short-circuited coils. The table shows the results of such a case:

Current Applied	*Amperes*	*Volts* *A—B*	*B—C*	*A—C*
A—b	15.5	70	34	36
b—C	15.5	34	70	36
A—C	14.7	35	35	70

Short-circuited coils can sometimes be burned out, otherwise the location test will be necessary.

An open-circuited coil will be evident at once, since no current will flow in that phase.

Poor contacts between coils will give an increased drop across the phase containing them. By stripping the tape from the stubs they may be readily located without further testing.

A few coils made up of the wrong number of turns are occasionally placed in a winding. This causes only a slight unbalancing of the phases and is probably the most difficult error to detect. An example of an error of this sort in a two-phase winding follows. Current taken in each phase repeatedly with the same applied voltage was:

$$A_1 - A_2 = 41.2 \text{ amperes}$$
$$b_1 - b_2 = 40.3 \text{ amperes}$$

The cross connections were examined and found correct. The drop across each phase was then taken with the two phases in series. $B_1 - B_2$ was the higher, showing too many coils to be in phase B or too few in phase A. The drop across each group was then measured, indicating two groups in phase B with too small a drop. Next the drop across each coil was taken. These readings should begin low at the edge of the group, increase steadily to a maximum at the other end or beginning at a maximum, decrease steadily to a minimum. They did not do so. The drops of the coils of one group are given, also those of a correct group:

	Volts	
Coil	*Correct Group*	*Faulty Group*
1	2.72	2.71
2	3.22	3.21
3	3.75	3.73
4	4.00	3.98
5	4.10	3.83.
6	4.15	4.13

The readings across the faulty group increased steadily until coil (5) was reached. This drop was low, showing too few turns in that coil. These readings were obtained with both phases in series. If only one phase was connected to the line the readings would increase to coil (3), coil (4) being the same as (3), then decrease symmetrically; (5) equal to (2) and (6) equal to (1). The field due to the second phase when both are in series causes the difference. Another coil of too few turns was found in the other group which gave a small drop.

The photograph, Fig. 6, shows the switchboard used in making these tests. Fig. 7 is a diagram of the switchboard connections. The board is fed from a 220-volt, 7200-alternation circuit This enters, through a circuit-breaker and switch, to the primary of a 10 kw transformer. The secondary of this transformer is wound for 465 volts and provided with 13 taps leading to as many plug-sockets. The voltage between the taps is given in the figure. By inserting the plugs in two of the sockets any voltage, varying, generally by 5-volt steps, from 5 volts to 465 volts is obtained. These variations are necessary to obtain a proper current in the different types of windings. The ammeter has 10 and 60-ampere scales, being connected to the two series transformers. Either series

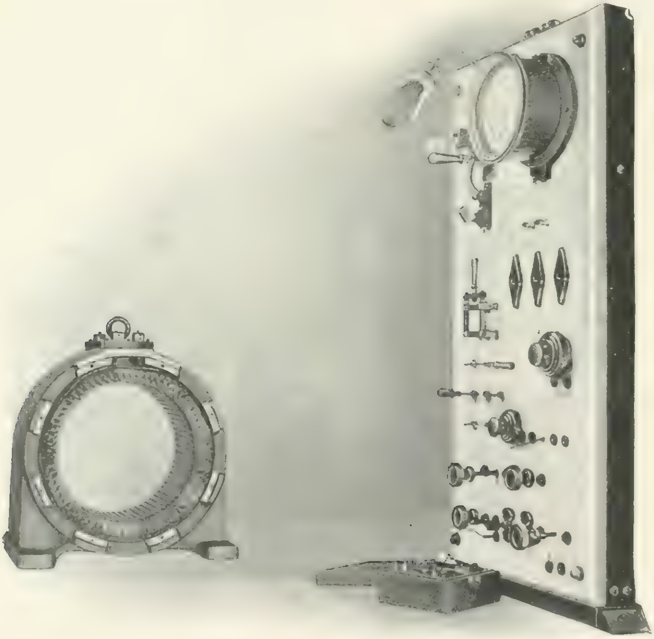


FIG. 6—TESTING SWITCHBOARD

transformer is put in circuit and the other cut out by changing one plug from one to the other of the two three-part sockets. It is also impossible to open the secondary circuit when the primary is in circuit. By means of the four-plug switches and the single-pole

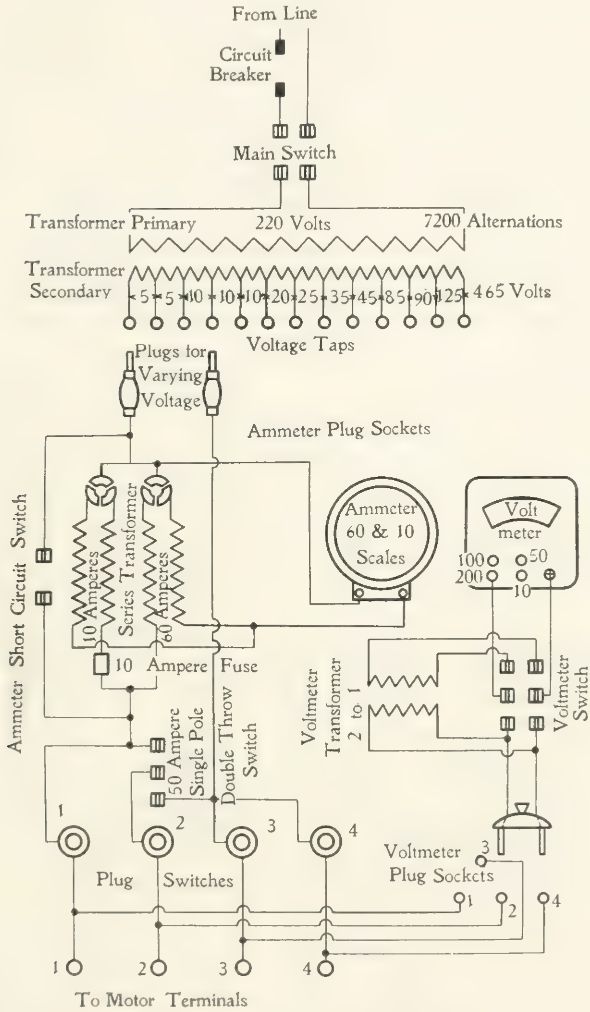


FIG. 7—CONNECTIONS OF TESTING SWITCHBOARD

double-throw switch the supply-circuit can be connected to any phase of a three-phase or two-phase motor without changing the connections at the motor. The four voltmeter sockets enable any voltage to be read independently of the current connections.

An example will serve to explain the operation of the board. A three-phase winding will be taken. The three motor terminals are connected to leads (1), (2) and (3) from the board, and no further attention to the motor connections is necessary. The voltage is adjusted to suit the winding or test. If 75 volts give a convenient current the plugs are connected to taps (3) and (8) of the transformer. The ammeter scale, 60 or 10, is chosen, which gives the best deflection. If it is the 10, the ammeter plug is inserted in the socket at the left. Say we wish to first feed current to phases *A* and *B*. Throwing the single-pole switch down and closing the plug-switch (2) connects the socket (2) to which phase *B* is wired. Then by closing plug-switch (1), *A* is connected. By opening the ammeter short-circuiting switch the current *A—B* is observed. For 75 volts the 100-volt scale of the voltmeter is used without the voltmeter transformer, so the voltmeter switch is thrown down. Putting the voltmeter plug in sockets (1) and (2) we have the voltage *A—B*. Changing to (1) and (3) gives the voltage *A—C*, and to (2) and (3) gives the voltage *B—C*. These are all the readings necessary with current in phases *A* and *B*. Opening plug switch (2) and closing (3) will put the current in *A* and *C*. The voltage readings are similar. Throwing the single-pole double-throw switch to the upward position, opening plug switch (1) and closing (2) puts the current in *B* and *C* and the voltmeter readings are repeated. This is all the manipulation for the complete set of observations, providing the winding is correct. If it is not correct, the current may be sent through the required phases and voltmeter leads carried to the motor and the drops taken which are necessary to locate the error.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

I.—ELEMENTARY EXAMPLES

By V. Karapetoff

A Series of Lectures Delivered Before The Electric Club October-November, 1903.

THE graphical representation of physical phenomena in the form of curves and diagrams is now very extensively used in all branches of engineering. This is to be ascribed to the comparative facility with which we grasp a new idea if clothed in geometrical form. Geometrical conceptions, as pure conceptions of space, are the simplest of all our conceptions and are familiar to us from our earliest childhood. Therefore, any electrical or mechanical problem, if reduced to geometrical form, becomes much easier to understand than in any other way.

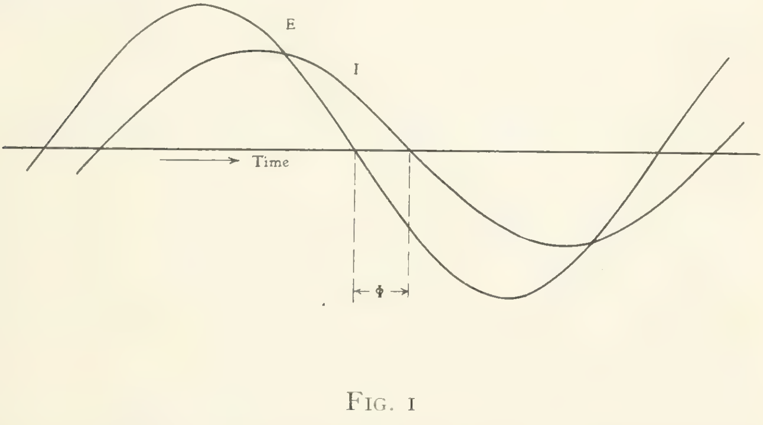


FIG. 1

The object of these lectures is to give the graphical representation of the more important phenomena in alternating-current circuits and of the properties of alternating-current machines and apparatus. The properties of direct-current circuits are assumed to be known, as well as the conception of sine waves, and of the physical meaning of self-induction as due to the inertia of the magnetic field. It may, however, be worth while to point out the fundamental ideas on which vectors are based. Instead of representing the instantaneous values of e.m.f. and current in a circuit by the sine waves *E* and *I* (Fig. 1) it is possible to represent them by two lines *E* and *I* (Fig. 2). The lengths of these lines are equal to the maximum or effective values of the two sine waves, and their relative positions to the difference of phase between them. Thus with the waves, curve E is leading curve I by the time or distance corresponding to the time, Φ positive, time being assumed in the direction of the arrow; that is, curve E passes through its maxima and minima that much earlier than curve I. With the vectors (Fig. 2) the same idea is expressed by the curve I following the curve E by the same time, or angular distance, Φ, the vectors rotating in the direction of the arrow. All vectors representing similar quantities, such as e.m.f.'s., should be drawn to the same scales, but the scale of vectors representing different qualities, e.m.f. and current for example, are absolutely independent, since they are never added together nor subtracted from each other. The further properties and applications of vectors can best be explained in connection with specific examples.

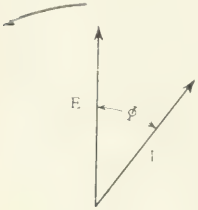


FIG. 2

Circuits Containing Ohmic Resistance—The simplest alternating current circuit, consisting only of ohmic resistance (e.g. incandescent lamps) does not differ in its relation between e.m.f. and current from an ordinary direct current circuit (Fig 3). The current I is in phase with the e.m.f. producing it, and at every moment is equal to: $I = E \div r$, where r is the ohmic resistance of the circuit. Accordingly the vectors E and I have the same direction as shown in Fig. 4.

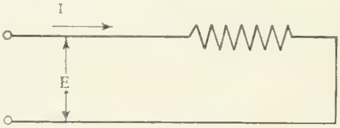


FIG 3

Circuits Containing Self Induction—The other extreme circuit is a circuit consisting of a purely inductive resistance (Figs. 5 and 6). The current here is lagging 90 degrees behind the applied e.m.f., and is a wattless current, supplying no energy whatever. Such a case could hardly be realized in practice, because of ohmic resistances and iron losses, indispensable in all practical apparatus; to some extent this is realized in the case of a generator supplying induction

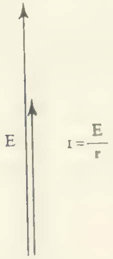


FIG. 4

motors running on zero load. The current shown by the ammeter may be up to one-third of the normal current taken by the motors at full load, but the wattmeter would indicate only a very small amount of energy.

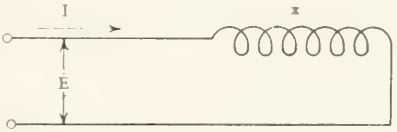


FIG. 5

In this case, as before, if the inductive resistance is x, the current is equal to: $I=E\div x$. The only difference between this case and the case of ohmic resistance is that the current is lagging 90 degree behind the e.m.f. instead of having the same phase with it.

Circuits Containing Ohmic and Inductive Resistances—Now we shall consider the three following combinations of ohmic and inductive resistances in a circuit:

(1) Series connection of ohmic and inductive resistances.

(2) Parallel connection of ohmic and inductive resistances.

(3) Series-parallel connection of ohmic and inductive resistances.

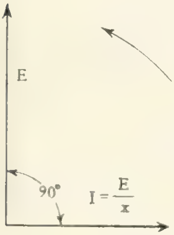


FIG. 6

Connection of Ohmic and Inductive Resistances in Series—Figs. 7 and 8 show this circuit and the corresponding vector diagram. This diagram contains a triangle of e.m.f.'s, the vector I of the current and the angle Φ of lag between the current and the applied e.m.f. We have to distinguish between a case in which the current is given and a case in which the e.m.f. is given. When the current is known, the triangle can be constructed as follows:

The pressure at the terminals of the circuit is the geometrical sum of the pressures at the ends of the ohmic resistance and of the inductive resistance. These component pressures can be found as explained above; that is, the pressure at the terminals of the ohmic resistance equals Ir (line AB) and has the direction of the vector I. The inductive drop equals Ix (line BC) and leads the current by 90 degrees. The resultant terminal pressure *E* is the geometrical sum of *AB* and *BC*, and is represented by the hypothenuse *AC* of the triangle. Vectors are added together like mechanical forces—according to the parallelogram rule. The parallelogram is completed in Fig. 8 by dotted lines, but as will be readily seen, the left half of the parallelogram is not at all necessary. The same result can be obtained by simply drawing vector *BC* from the end of the vector *AB* and then by completing the triangle. We shall use the general parallelogram rule for addition and subtraction of vectors in this form.

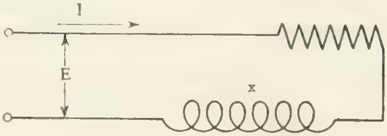


FIG. 7

To add two vectors *a* and *b* draw from the end of *a* a line equal and parallel to *b* and complete the triangle. The third side *c* is equal to the sum *a*+*b* (Fig. 9).

To subtract *a* from *b* (Fig. 10) draw from the end of *a* a line equal and parallel to *b*, *but in the opposite direction*, and close the triangle. The resultant side *d* is equal to the geometrical difference *a-b*. Both these rules can be very easily checked up with the usual parallelogram rule by completing the triangle as shown by dotted lines.

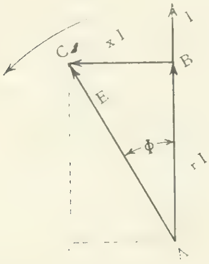


FIG. 8

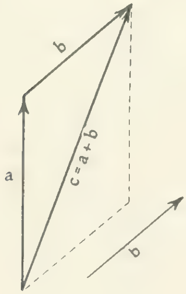


Fig. 9

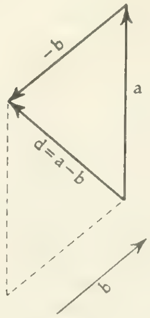


Fig. 10

If the voltage is given and the current is unknown, first assume any value of current whatever, and construct the triangle as before (Fig. 8). This will give a terminal pressure E_1, which, as a rule, will be different from the given e.m.f. E. Then simply reduce the triangle in ratio $E_1:E$. The assumed current I_1 is also to be reduced in the same ratio to get the true current I.

Other problems can be solved by means of the same triangle, for instance to find the resistances r and x, if the value of the current I, the applied e.m.f. and the angle of lag Φ being given. In this case describe a circle with the vector E as a diameter (Fig 11) and draw a line AB at an angle equal to Φ, so as to intersect the circle. Then the triangle ABC can be completed. Its sides AB and BC give the values of the drop in both resistances, and the side AB gives the direction of the current. Dividing AB and BC by the current we find the values of the corresponding resistances r and x.

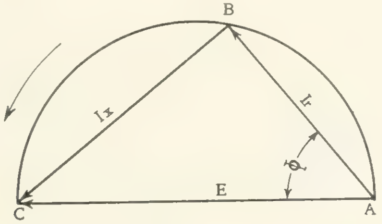


Fig. 11

The triangle of e.m.f.'s (Figs. 8 and 11) is of so much importance in the study of alternating-current phenomena, that it will be worth while solving additional problems to illustrate its application.

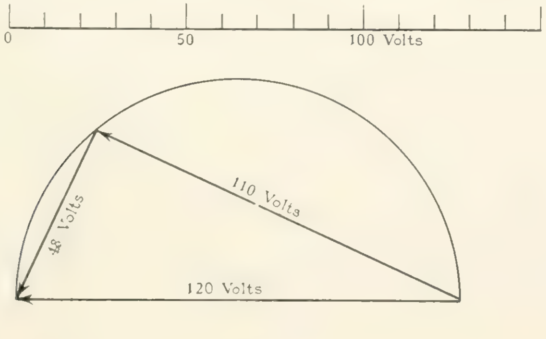


FIG. 12

Choke Coil in Series with Lamps—A group of fifty 100-volt lamps is to be connected to a 120-volt circuit. A choke coil has to be inserted in series with the lamps in order to reduce the pressure from 120 volts to 110 volts. It is required to find the necessary inductive resistance of this choke coil and the voltage drop in it. All the lamps are supposed to burn simultaneously. The lamps can be considered as a purely ohmic resistance, and the choke coil as an inductive resistance so that this is the same problem as before—series connection of ohmic and inductive resistances. The ohmic drop is given (it has to be 110 volts); the total pressure is also given (120 volts). Hence, the triangle of voltages can be easily constructed (Fig 12); the inductive drop is found to be equal to 48 volts. If we assume that each lamp consumes about 0.5 amperes, the total current would be 25 amperes, and the inductive resistance of the choke coil $48 \div 25 = 1.92$ ohms.

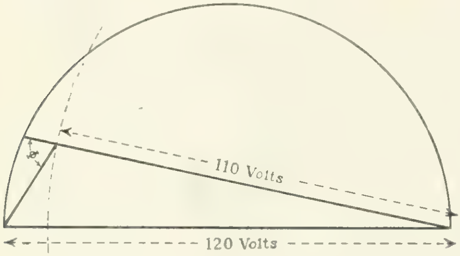


FIG. 13

Practically, the phase difference between the current and the terminal pressure in a choke coil can never be made 90 degrees because of its iron-loss and ohmic resistance. The triangle takes a form shown in Fig. 13. This triangle can be constructed if the power-factor of the choke coil is known to correspond to the angle Φ. The choke coil itself can be properly designed if the voltage at its terminals and the current flowing through it are given.

Regulation of a Transmission Line—A transmission line has an ohmic resistance of 0.75 ohms and an inductive resistance of 2.7 ohms. The voltage at the receiver end is required to be kept constant at 3,000 volts. What will be the voltage at the generator end at the full-load current of 200 amperes and at power-factors equal to 100 percent, 80 per cent and 0 percent ?

First of all calculate the ohmic and inductive components of the drop.

Ohmic drop—$0.75 \times 200 = 150$ volts.

Inductive drop—2.7x200=540 volts.

The small triangle representing drop in the line can now be constructed in its three positions according to three different values of the power-factor (Fig. 14). On this figure the positions of the current and of the triangle marked (1) correspond to the power-factor of 100 percent, those marked (2) correspond to 80 percent, and those marked (3) correspond to 0 percent (purely inductive load, the worst case for regulation). The small side of the triangle is parallel to the direction of the current (ohmic drop), and the other is perpendicular to the direction of the current vector (inductive drop). Line *OA* is equal to 3,000 volts. The voltage to be maintained at the generator end is represented by three vectors *o1*, o2, *o3*. Each of them is the geometrical sum of 3,000 volts and the hypotenuse of the drop triangle (this hypotenuse represents the total drop of the line). These three vectors, being measured, are equal to 3,200 volts, 3,475 volts and 3,550 volts, corresponding to the power-factors, 100 percent, 80 percent, and 0 percent. The total drop in the line is the same in all three cases (hypotenuse of the small triangle, equal to 560 volts), but the vector of this drop is subtracted from the original pressure in three different positions, being the more unfavorable with the lower power-factor.

The case considered in this example is one of the most important practical applications of vector diagrams. A few additional remarks may therefore be found of value. In some cases voltage is kept constant at the generator end, instead of the receiver end of the line. It is left to the reader to apply the foregoing diagram to this case. The inductive resistance of a line can be found by test by short-circuiting it at the receiver end and sending through it a considerable current from the generator. Suppose the current to be 100 amperes at 280 volts at the generator terminals. Ohmic resistance, as measured by direct current is assumed to be 0.75 ohms; therefore, the ohmic drop is 75 volts. As the total drop is 280 volts, the inductive drop will be: $\sqrt{280^2 - 75^2} = 270$ volts.

The same may be found graphically by constructing a rectangular triangle having one side equal to 75, and the hypotenuse equal to 280. The other side will be 270. The inductive resistance of the line is: $r = 270 \div 100 = 2.7$. as was given before.

Fig. 14 refers to a single-phase transmission line. For a two-phase, four-wire line the diagram is the same as applied to a single-phase line transmitting one-half the power at the same voltage. The inductive resistance of the line can be found here also by short-circuiting one of the phases, provided there is no inductive interaction between the two circuits. Likewise for a three-phase, three-wire line having the wires equally distant from one another the diagram is the same as applied to a single-phase line consisting of two of the wires transmitting half of the power at the same voltage. It follows therefore that the addition of one wire to the two wires of a single-phase circuit provides conductors for a three-phase circuit which will deliver twice the power with the same percentage loss in voltage and in power. The weight of copper per kilowatt delivered in three-phase transmission at a given voltage and with given loss is therefore 75% of the weight required for single-phase transmission. For a three-phase system the same diagram can be used in another way, as it can be constructed for one wire, if the voltage used is the pressure between the line and the neutral point, and not the pressure between the wires. An example may make it clearer. We short circuit all the three wires at the receiver end of the line and send a current through the line. Suppose the readings of the ammeter in each leg to be 100 amperes and the

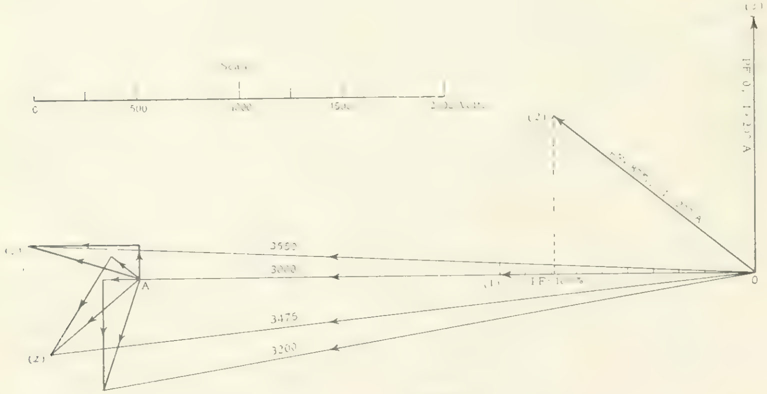


FIG. 14

voltage between the wires 250 volts. The ohmic resistance of each wire is supposed to be 0.35 ohms. Both drops have to be referred to the star voltage, that is to the voltage between the line and the neutral point of the system. This is $250 \div \sqrt{3} = 144.5$ volts. The inductive drop is: $\sqrt{144.5^2 - (0.35 \times 100)^2} = 140$ volts.

In applying these data to the determination of the regulation as in Fig. 14, the voltage between the wire and the neutral point, $3000 \div \sqrt{3} = 1732$, must be used and not the voltage between the wires, 3000. This follows directly from the general properties of three-phase circuits.

The shape of the diagram Fig. 14 does not depend on the absolute values of the ohmic and inductive resistances, but on *percentage drop* relative to the original voltage, E. Therefore, assuming the original voltage to be 100 per cent, it is possible to represent all the triangles, three of which are shown in Fig. 14, in a chart for all cases, instead of constructing them for each separate case. Such a chart has been given by Mr. Ralph D. Mershon in his article "Drop in Alternating-Current Lines," published in the *American Electrician*, June, 1897, and reprinted by the Westinghouse Electric & Manufacturing Company in pamphlet form, supplemented by a description of the Westinghouse compensator, originally designed by Mr. Mershon. Lately a similar chart has been published by Mr. F. G. Baum, of Leland Stanford, Jr., University. Mr. Baum's chart or "Alternating Current Calculating Device" consists of two parts; one drawn on pasteboard, and the other on a sheet of transparent celluloid. By bringing this last chart in a suitable position relative to the other, the total drop or the regulation of a line can be immediately read off for any power-factor. The article of Mr. Mershon and the device of Mr. Baum, together with its explanatory book are earnestly recommended to the attention of those interested in the drop and regulation of an alternating-current line, the more because both can be used for calculating internal drop in a transformer, an alternator, for determining the working conditions and phase relations of a synchronous motor, and many other similar problems.

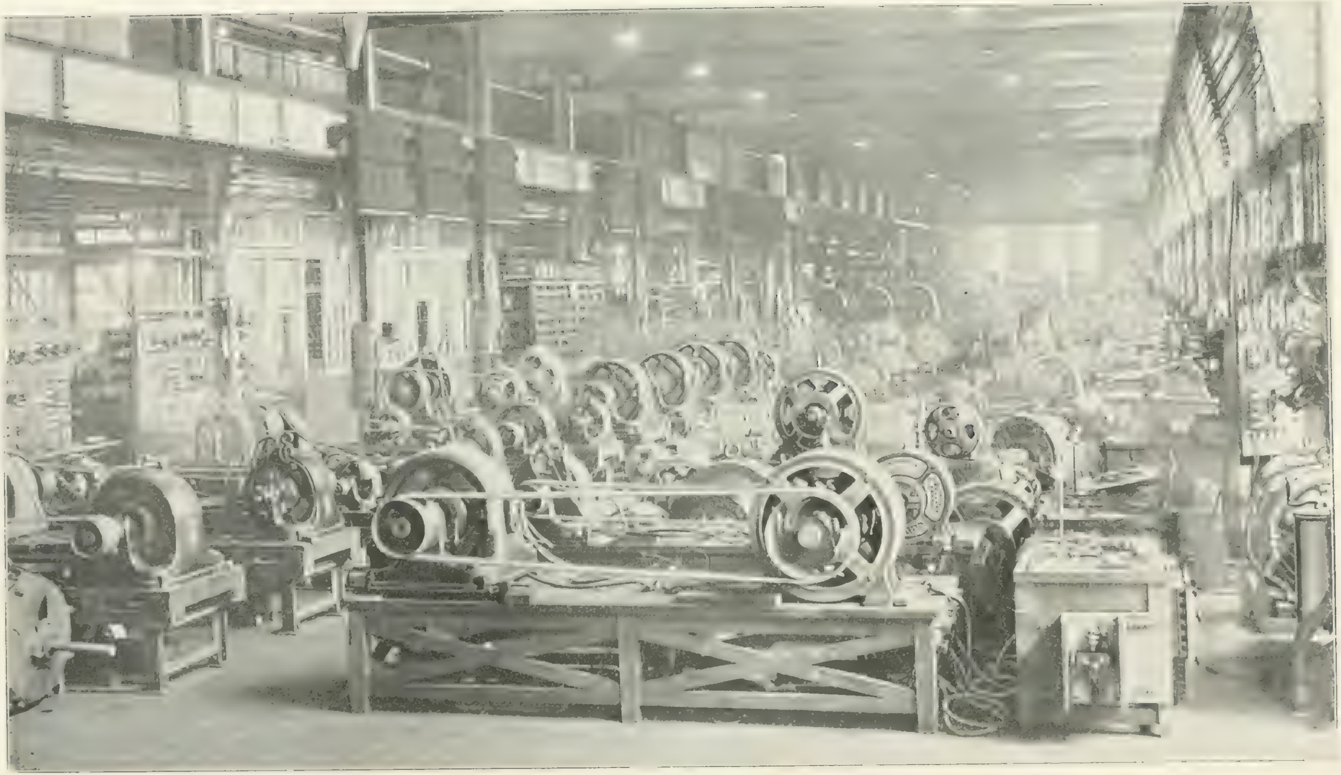


FIG. 10—TESTING DEPARTMENT, IN WHICH MACHINES UNDER 100-KW ARE TESTED

FACTORY TESTING OF ELECTRICAL MACHINERY—III

By R. E. Workman

Iron Loss, Friction Loss and Saturation Tests of Series Motors—These tests may be made in exactly the same way as with shunt or compound wound machines, and this is sometimes done. Owing to the fact that the series motor is not a constant speed motor, when a separate driving motor is used, a number of separate runs at different speeds must be made. The following method, which does not require a separate driving motor, is more convenient both in the performance of the test and in the derivation of the desired results from the experimental data. It is therefore more frequently used. If a series motor has its full voltage applied with no load upon it, it will run at a very high speed, the small current in the armature, necessary to drive it, resulting in a very weak field. If, however, a resistance is shunted across the armature, the field has a larger current through it than the armature, and consequently the speed for a given armature current is reduced. This shunt to the armature may be varied so as to vary the speed of the motor within desired limits, and the input to the armature will represent, very approximately, the power necessary to overcome the friction, windage and iron loss of the motor at that particular speed and field current.

The friction losses are found separately by means of the following test. A low voltage is applied to the motor, so that it may run at a low speed with no load, and this voltage is gradually increased, in order to get something like the range of speeds at which the combined iron loss and friction test was taken. Running under these conditions, the strength of the field is so small that the iron loss may be neglected and the input of the motor will give very approximately the frictional losses for each speed.

(a) Iron Loss and Friction Loss—The connections are shown diagrammatically in Fig. 11. The table used is that shown in Fig. 12, and the connections are made as shown in that diagram.

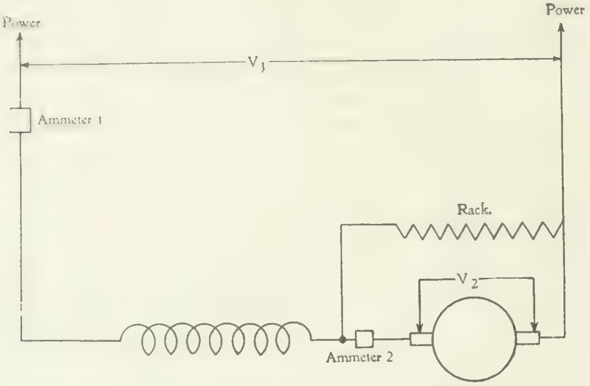


FIG. 11—IRON LOSS AND FRICTION TEST.

Preparations for Test—A rack is inserted across L_1 L_2 in order to vary the speed of the motor. The motor is then started up by means of a starting rheostat, the rack being shunted across the armature by throwing the switch $I L_1$ to the right. An ammeter is put across the switch $A S_1$ by means of the terminals shown, this switch being opened in order to measure the current in the armature. The main ammeter is put across the other terminals shown, its short-circuiting switch being also indicated. The line and field voltages are read by means of sockets and plugs, not shown in the diagram.

Conduct of Test—Referring to Fig. 11, V_2 is to be held constant by means of a rheostat in the field of the booster. The main current is varied by varying the resistance of the rack.

As the current in the main circuit is increased, the drop in voltage in the series field will increase, thus increasing V_1. Ammeter (1) measures the main current and ammeter (2) the armature current, which when multiplied by the armature voltage V_2 gives the input to the armature. The readings taken are speed, main amperes, armature amperes and armature volts. Three sets of readings are taken for different values of V_2 which is to be held constant for each set of readings.

(b) FRICTION LOSS—The machine is run as an ordinary series motor on low voltage, being run without load at various

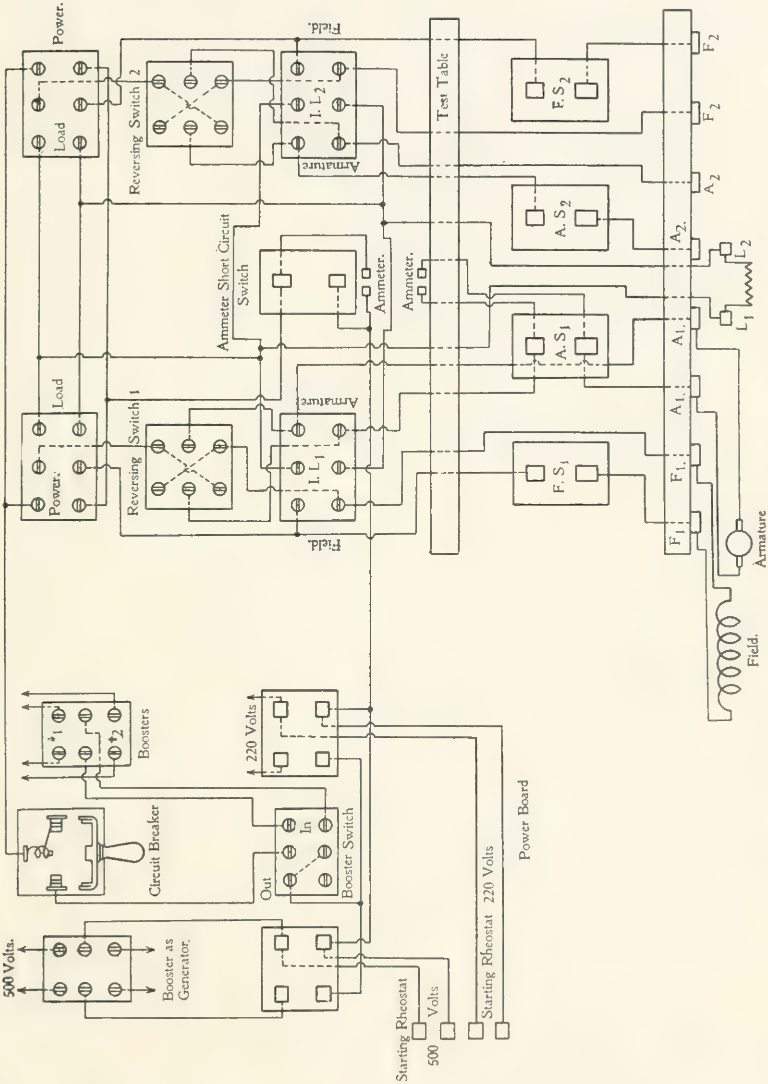


FIG. 12—EXPERIMENTAL TABLE FOR TESTING SERIES MOTORS

speeds, depending on the voltage used, and within a similar range to that used in the case of the combined iron loss and friction loss test. The connections are the same as those shown in Figs. 11 and 12. except that, in this case, no shunt is used across the armature, and consequently the field and armature currents are equal. The readings taken are, speed, armature volts and armature amperes. The armature input or the product of armature volts and armature amperes gives, as before, the loss in the armature. As above mentioned, the iron loss with such a weak field as is used in this test, is negligible, so that the armature input represents the friction loss simply.

Precautions to be Observed—This test should be made both before and after the combined iron loss and friction loss tests, and a mean of the results taken, to allow for changes in the friction due to change in temperature, etc. Too much importance should not be given to the readings taken at high speeds, as here the current and the iron loss become so great as to vitiate the results quite appreciably.

Working up Results—From the combined iron loss and friction loss test, the products of armature volts and amperes for each reading, or the sums of iron loss and friction loss in the motor, and also the field amperes, are plotted to the speed of rotation. From the friction loss tests the products of armature volts and amperes for each reading or the friction losses of the motor are plotted to the speed of rotation.

These curves for a No. 95 railway motor are shown in Fig 13. Specimen readings, from which these curves were plotted, are given below.

Friction test before iron loss and friction loss test:

Armature Volts V_2	Main Amperes	Watts	R. P. M.
100	5.05	505	838.5

After iron loss and friction loss test:

Armature Volts V_2	Main Amperes	Watts	R. P. M.
100	5.00	500	846

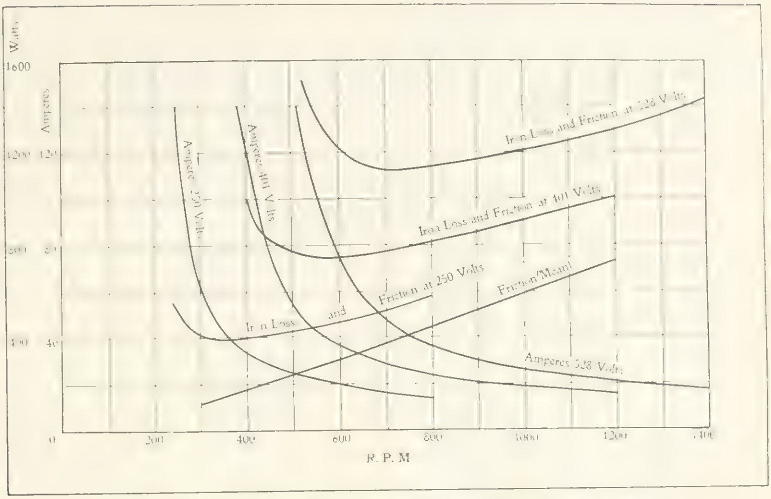


FIG. 13—IRON LOSS AND FRICTION CURVES

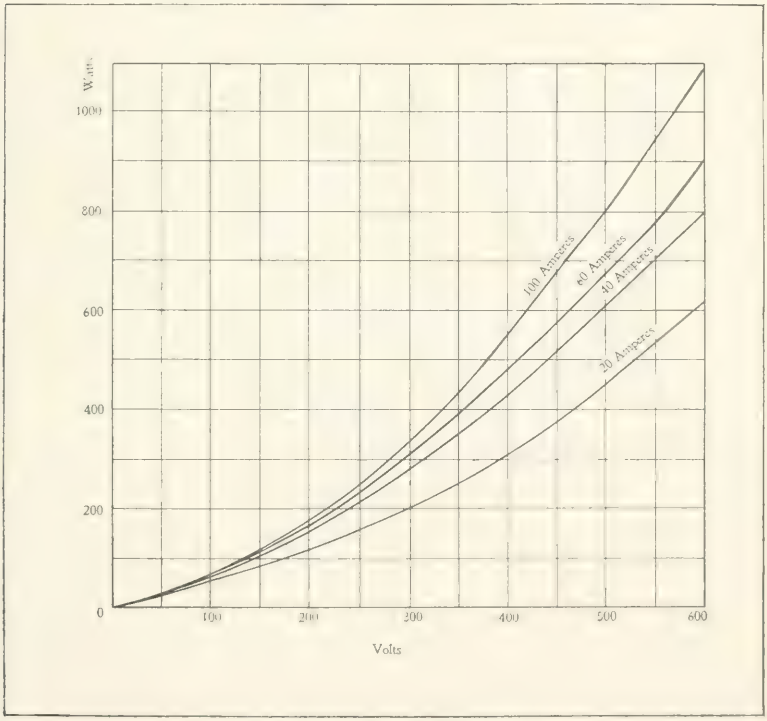


FIG. 14—IRON LOSS CURVES

Iron loss and friction at 528 volts:

Armature Volts	Main Amperes	Armature Amperes	Watts	R. P. M.
528	100	2.54	1,340	553

In each, the watts are found by multiplying together the armature volts and the armature amperes.

As these curves are very awkward for reference purposes, and as it is desirable to be able to read off directly the iron loss for a particular voltage across the motor terminals for a number of different currents through the motor, a set of curves of iron loss shown in Fig. 14 is calculated from the curves already plotted.

Amperes Main	Volts drop in Motor	V_2 =250 Volts		V_2 =401 Volts		V_2 =528 Volts	
		V_2+ Drop	Watts	V_2+ Drop	Watts	V_2+ Drop	Watts
20	12.6	262.6	170	413.6	326	540.6	520
40	25.2	275.2	240	426.2	470	554.2	708
60	37.8	287.8	288	438.8	554	565.8	812
100	63.0	313	360	464	714	591	1,072

The main amperes and the watts are read off from the curves on Fig. 13 at equal speeds. The total resistance of the motor at 75°C is .628 ohm. It is necessary to add the volts drop in the motor to the armature voltage used in these tests, so as to give the line voltage which would be applied to the motor when working under ordinary conditions, with the same main current. The drop in the armature with such a small current as is required to overcome the losses alone, is negligible. The watts in the table are the amounts of the iron losses corresponding to the particular voltage and current at which the reading was taken. A curve is plotted for each current, three points on each curve being given in the above data. Watts iron loss are plotted to "volts + drop."

SATURATION TEST—The saturation curve of a generator or motor shows the relation of the open-circuit voltage to the field current when the machine is driven as a generator at constant speed with its field separately excited through a range of values. In the case of shunt and compound-wound machines the shunt field is used to supply the excitation and the current in it is used in plotting the curve of saturation. In the case of series motors the series field is of course used. To make the saturation curve independent of the number of turns in the exciting winding, the voltage may be plotted to the product of the field current and the number of turns in series in the winding, or the ampere turns. The saturation curve is taken to test the correctness of the machine in three different respects:

(a) Accuracy of manufacture, especially as regards the radial depth of air gap and the number of turns on the field coils.

(b) Quality of iron and steel in the magnetic circuit.

(c) Accuracy of the engineer's calculations.

The readings are taken from the iron-loss test and plotted as shown in Fig. 15, which gives the saturation curve of the 500-kw generator, whose iron-loss curve is shown in Fig. 9. It will be observed that the curve is practically straight for some distance, rising rapidly from near the origin and then bending over so as eventually to become parallel to the axis of abscissae. If there were no retentivity in the magnetic circuit the curve would pass through the origin. As is well known, the permeability of air is constant, but very small, whatever the intensity of the field traversing it, while that of the magnetic metals is at first very great, but

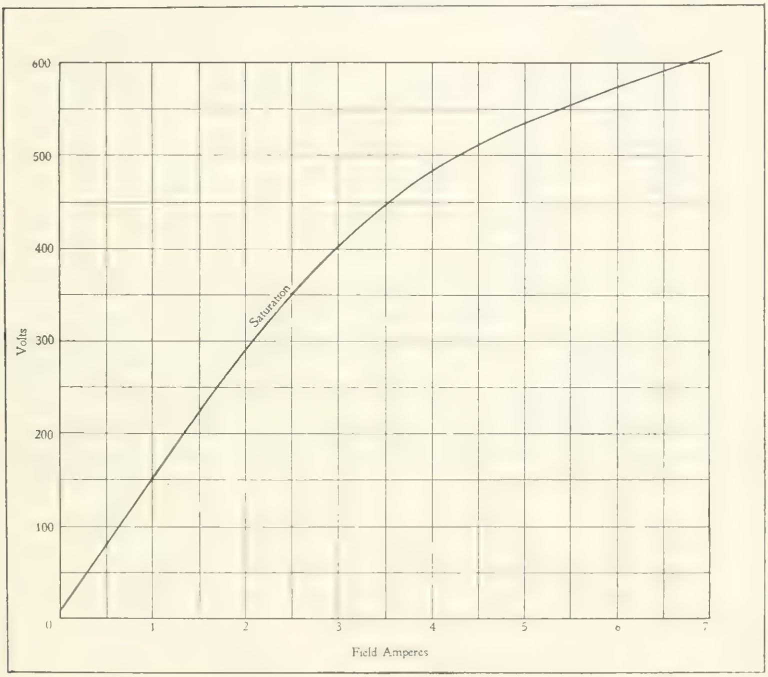


FIG. 15—SATURATION CURVE

falls very rapidly with the intensity. Hence, when there is a weak field in the magnetic circuit of the machine, the air gap constitutes the greatest part of the reluctance, that of the steel being practically negligible. The consequence is that when the field is weak, the saturation curve rises in a straight line; when, however, the field becomes stronger, the proportion of the reluctance of the air gap to that of the rest of the circuit is altered, the total reluctance rising with the magneto motive force, and the curve bends over as shown.

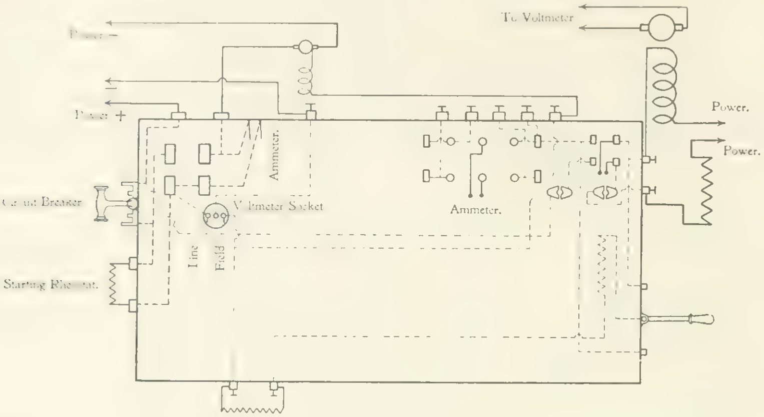


FIG. 16—EXPERIMENTAL TABLE FOR LOSS TESTS AND BRAKE TESTS UNDER ABOUT 20-HP.

It is usual to plot both the iron loss and the saturation curves on the same sheet of paper; this is done merely for convenience in plotting.

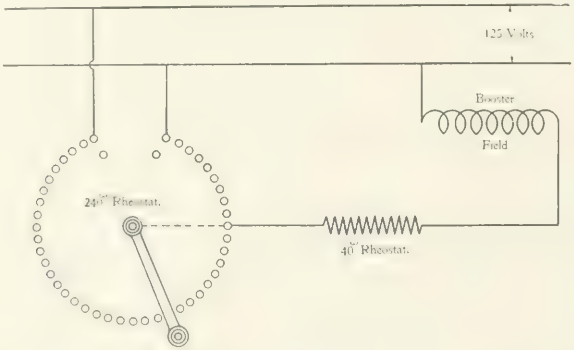


FIG. 17—A VERY CONVENIENT ARRANGEMENT OF RHEOSTATS, FOR VARYING THE VOLTAGE OF A BOOSTER

The 40-ohm rheostat is used for fine adjustment when the booster-field is across a very small proportion of the 240-ohm rheostat

(TO BE CONTINUED)

THE MAKING OF A MAN BY MEANS OF THE APPRENTICESHIP COURSE

By Frank H. Taylor, Second Vice President of the Electric Company

An abstract of an Address before THE ELECTRIC CLUB, February 15, 1904

MR. TAYLOR'S address was in the nature of an earnest, practical and inspiring talk, informally delivered, with many touches of humor. He said in substance:

I have chosen this subject because I have been asked to reply to several questions which show what our apprentices feel is the problem before them.

I am first asked: "What are the advantages of the apprenticeship course which cannot be classed as strictly technical or professional in character, but which give a broader training that may be of advantage in any business or profession?"

As we benefit in college by things which we never dreamed were contributing to our education, so in apprenticeship work, we cannot say beforehand what will do us the most good. There is a benefit in living and working with men who expect to spend their lives as wage earners. You may obtain from the working men an undefined wisdom which has been the portion of labor since the world began. You can learn what is of first importance, sympathy with the laboring man. You can observe the working of a great organization in its details; learn the necessity for system, economy and co-operation. You have the opportunity of observing experienced technical men. To see able men doing work of high character is an inspiration to good and faithful performance of any kind. Even to watch George Westinghouse walking through the works may be, to an observing man, the beginning of a liberal education. You have also in this course the advantage of comradeship with one another—men of the same generation, who are together to aid in the great forward movement of the industrial world. The apprentice who shuns The Electric Club and the apprentices' dinners loses much of this broadening influence. The right judgment of men is the key to all professions.

The next question relates to the essential qualifications for apprentices entering the various departments of the Company, viz: sales, engineering, construction or commercial.

I hesitate to answer this question lest I might discourage some men from attempting that for which time and experience may qualify them. The electric business is greatly in need of men. You are more or less looked after, and your qualifications for certain positions are likely to be gradually made manifest to those who are directing you. Each man must also watch himself and grasp the opportunities offered when he feels fitted to make use of them. Keep on with your work, and wait until the business needs you. What you must do is to know some part of it better than any one else knows it, and you will become, just as sure as the sun rises, a competent man in your generation. Be good sportsmen—play the game fair. Don't take a mean advantage of another. Keep on working; do not hurry unduly, and you will get the best out of the course.

Engineering requires real mathematical powers and some inventive gift. Selling, often thought most attractive, is really the hardest to accomplish. When I went into a manufacturing business the last thing I thought I could do was to sell. The power to do so came after years of experience. Selling requires knowledge of human nature, courage—a certain pleasure in a fight. Salesmen have many hardships. They are not employed in regular, accurate work, are obliged to live much away from home, and exposed to the temptations of dissipation. They are also specially liable to get the "big head" and to be suddenly "dumped." The department of erection and construction offers good preparation for the work of a salesman. You may there learn the secret of making a customer sign his name to a paper, which is the essense of taking a contract. Men in this department are often made salesmen by very force of circumstances. An apprentice may look to selling as an ultimate thing, after the necessary experience of life has been obtained. The later you take it up the better.

I am surprised that the question, in its enumeration of the various departments of the Company, has omitted shop practice. I believe the line of work which offers most to apprentices is the preparation for the management of great properties.

The third question asks, "When should an apprentice devote his energies and acquired training to the attainment of material prosperity, and less to study; or when is a man fully capitalized with general education, and how can he tell the point of maximum efficiency?" To this point I answer "Never." The best man is he who can keep broadening out as the opportunity broadens. It is sad to see how many men fail to keep growing with their work. They do well up to a certain point, and then because the demands of a great organization are made before the man is mature, are overwhelmed and useless. Be watchful that you keep growing. Your career should be a constant evolution. There should be an evolution in minds as in affairs. The best men ripen slowly. Fruit should not be picked too soon, neither should it hang on the tree until it is rotten. Seize the opportunity when you are ripe for it.

Do not be troubled because there is in your minds vagueness, or undeveloped crudeness. It is a mistake to set one's mind too firmly upon reaching some fixed goal. A man must not worry about the mistakes he made in the early stages, while feeling for the next step Keep an open mind, so that every experience of life will teach you something, and contribute to your growth. A poor mind crystalizes too soon.

There was a time when the manufacturer looked doubtfully on the college man. Now there appears some danger that the situation be reversed, and the man without a college education has met with discouragement. I wish no one to think that a college education is necessary to success. Fresh vigor of mind is better than over-refinement, and a positive man who has failed to get to college can be educated here. Men who differ in birth, education and training will make a different product, but equally valuable, if equally in earnest.

Last of all, I will say emphatically, in the words of wise old Martin Luther, "All discouragement is of the devil."

Mr. Taylor then read and commented upon Kipling's poem, "Pharaoh and the Sergeant."

He held this poem as illustrative of the way in which the apparently long and dreary training, "the years that no one talked of," under a quiet, competent, faithful leader, may make successful men out of the crudest materials.

> "Said England unto Pharaoh: 'You've had miracles before
> When Aaron struck your rivers into blood;
> But if you watch the Sergeant he can show you something more—
> He's a charm for making riflemen from mud.' "

Mr. Taylor said, in conclusion: "The great problem for the business man in the future is the proper relation of capital and labor. "The condition of the workingman is not to be benefited so much by the laws as by the leaders. Among you may be some man who may show the way to industrial peace. He must be a man who can understand the needs both of capital and labor—the struggle of the workman and the problems of the employer. If one of you, trained under the influence of this Company, could find a way to lead the industrial world into a sympathetic understanding of the situation, and change the whole moral tone of these apparently conflicting interests, I would have more pride in such a man than in millions of dividends. You have not come to Pittsburg only to make a living. In the words of the late Governor Russell, of Massachusetts, 'There is one thing better than making a living; that is, making a life.' "

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

Conducted by M. H. Bickelhaupt

Generator Foundations—In erecting a large generator having a bed-plate to which the bearing pedestals were bolted it was found that the shaft had no end-play. The erecting engineer accordingly had the bearings taken out and faced off to give the shaft the proper amount of end-play, and reported to the factory that the machine had been shipped defective in this respect. An investigation brought to light the fact that the middle of the bed-plate had not been properly supported by the foundations, and the bed-plate had sagged, tilting the two bearings and bringing them nearer together, so that the space originally allowed on the shaft for end-play was taken up. The bearings were of the self-aligning type, so that this tilting had not interfered with the alignment of the bearings.—*Road Section.*

A Case of Railway Motor Bucking—An old roadman recently told the following story, illustrating how far one sometimes has to look for the cause of serious trouble: The motors on a certain street railway had been giving considerable trouble from bucking, and several men had been sent out to locate the trouble, but with no success. Finally a man was sent out with orders to stay with the job until the cause of the trouble was found. It was discovered almost by accident. As one of the cars was coming out of the barn the road man was amazed to see the motor buck on the level with no load. He immediately looked the motor over, and found a film of moisture on the commutator. The rest was evident. The car barn was built near a shallow lake, and watery vapors rising from the lake had condensed on the commutators of cars standing in the barn all night.

A Form of Speed Indicator—In motor testing it is often desirable to run the motor up to a certain speed, higher than the normal, to test its mechanical construction. To determine, approximately, when this speed is reached a device is sometimes used as an indicator which is shown in the sketch. A brass rod about eight inches long is fitted at one end to a small triangular steel pyramid through a ball and socket joint, with the joint out of line with the axis of the pyramid. At the other end a block B, is firmly attached to the rod and supplied with a thump screw, *T*, which allows the straight steel spring *S*, to be moved up or down through the block. *G* is a graduated piece of steel or brass attached to *S*. In using the indicator the pointed end is inserted in the end of the shaft and the apparatus held by the hand at the block. If the motor be running, the end of the rod next the shaft will describe a small circle which will tend to cause that part of the spring above the block to vibrate in the manner shown. This, however, the spring will not do unless the length of the spring or speed of the motor be such that the natural vibrations of the spring for a unit of time shall equal the number of revolutions of the shaft for the same time. In this case the amplitude of the vibration of the spring will be a maximum and easily observed. Under any other conditions the effect of the shaft in attempting to vibrate the spring is offset by the quicker or slower natural rate of vibration of the spring. The spring is moved up or down the block until the maximum vibration is obtained. The approximate speed may then be read on the scale *G*.

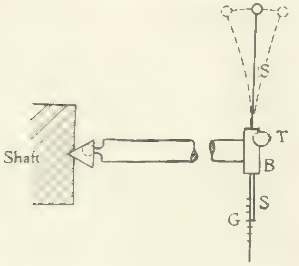
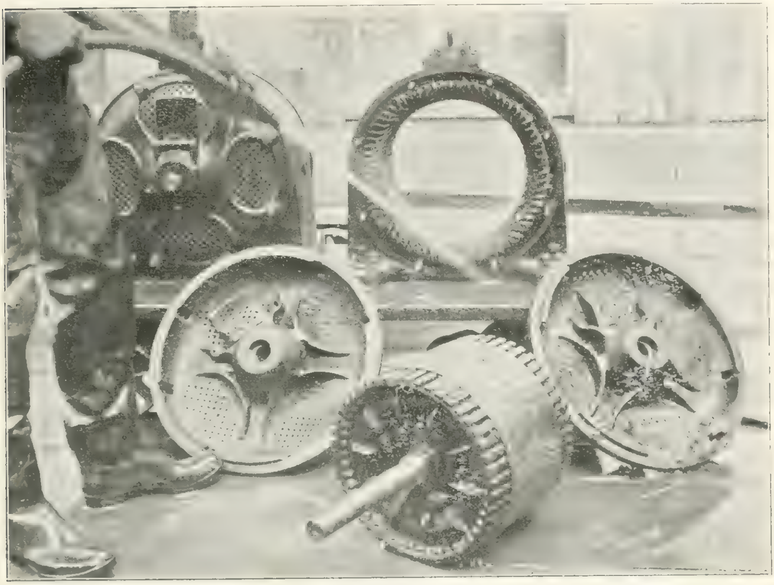


Fig. 1

Transformer Oil—It is very important that transformer oil should contain neither water nor acid. A simple test may be made to detect the presence of water. Take a few crystals of blue stone (copper sulphate, $Cu\ SO_4 + 5\ H_2O$) and drive off the water of crystallization by roasting. To the white powder that is left add a small quantity of the oil to be tested. If the oil contains water, the powder regains its blue color.

Acid may be most readily detected by blue litmus paper, which turns red when touched with acid.—*Road Section.*

Testing Insulation of Transformers—The specifications for the installation of high-tension transformers often call for an insulation test in which the test voltage is specified as that voltage which will just break down a given length of spark-gap. The proper way to make such a test is to measure the test voltage before applying it to the transformer under trial. The test voltage should be applied directly to the spark-gap and the voltage of the testing set raised till the spark-gap breaks down. The testing set should then be disconnected from the spark-gap and connected to the transformer to be tested. The adjustment of the testing set, being the same as that which gave a break down voltage on the spark-gap, gives the desired voltage for testing. If the spark-gap is left in parallel with the apparatus under test, and the voltage raised till the spark-gap breaks down, dangerously high voltages may be generated, because of the oscillatory character of the spark-gap discharge.



WASHING MUD OUT OF A TYPE C INDUCTION MOTOR WHICH HAD BEEN UNDER WATER DURING A FLOOD

A transformer may be made to generate its own test voltage by connecting one side of both high and low-tension windings to ground and putting double voltage on the low-tension winding. This subjects the high-tension winding to a voltage varying from zero at one side to double normal voltage at the other. The connections may then be reversed and the other side tested in the same way.—*Road Section.*

EDITORIAL COMMENT

Carnegie Gift to Engineering

A letter which promises to mark a new era in the development of American Engineering Societies was written by Mr. Andrew Carnegie on the 14th of March, addressed to the National Societies of Mechanical, Mining and Electrical Engineering and The Engineers' Club of New York. The letter contains but a single sentence, and reads as follows:

> "It will give me great pleasure to devote, say one and a half million dollars for the erection of a suitable Union Home for you all in New York City."

It has been generally known for about a year that Mr. Carnegie had proposed such a gift and that it originally included an additional engineering society and was for a less amount. As one of the Societies has seen fit to retain the building which it now occupies, instead of joining with the others in a new building, and as the first amount has been found inadequate the former letter has been superseded.

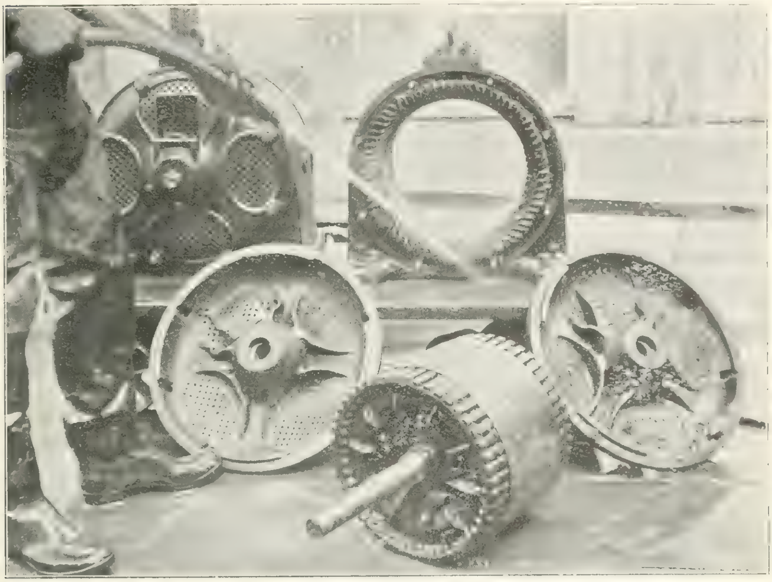
The Joint Committee having the matter in hand regards the gift as a trust for Engineering, to be administered not only for the Societies named, but for other societies of engineers, of which there are many which will be greatly strengthened and benefited by sharing in the use of the building. Aside from its auditorium, lecture halls, secretaries' quarters, committee rooms and the like, there will be provision for bringing together the present libraries of the Societies and making them a nucleus for a great American Engineering Library.

The space at command does not permit of an adequate expression of appreciation of Mr. Carnegie's generosity, nor of the great benefit which will result to the engineering profession from the increased facilities afforded the National Engineering Societies and the closer touch in which they will be brought through their occupancy of this common home. Mr. Carnegie has provided for both the professional and social sides of engineering life, as two abutting buildings are to be erected, one on Thirty-ninth street for the Engineering Societies, and the other on Fortieth street for The Engineers' Club.

One of the most notable characteristics of the development during the past generation has been the advance in all branches of its engineering work The next decade will undoubtedly see advancement even greater than that of the past 20 years. The Engineering Building will be a great material factor in promoting this advancement. It should be a matter of especial gratification to the members of THE ELECTRIC CLUB that one of its own number has had such an important part in the success of the undertaking. As is generally known, Mr. Charles F. Scott, Chief Electrician of the Westinghouse Electric & Manufacturing Company, was President of the American Institute of Electrical Engineers last year, and was summoned by Mr. Carnegie the day following an address at which Mr. Carnegie was present, in which Mr. Scott had spoken of the need of an engineering building. Mr. Scott has been indefatigable in his work in connection with the Engineering Building and is Chairman of the Joint Committee to which the enterprise has been entrusted.

W. M. McFarland.

which will just break down a given length of spark-gap. The proper way to make such a test is to measure the test voltage before applying it to the transformer under trial. The test voltage should be applied directly to the spark-gap and the voltage of the testing set raised till the spark-gap breaks down. The testing set should then be disconnected from the spark-gap and connected to the transformer to be tested. The adjustment of the testing set, being the same as that which gave a break down voltage on the spark-gap, gives the desired voltage for testing. If the spark-gap is left in parallel with the apparatus under test, and the voltage raised till the spark-gap breaks down, dangerously high voltages may be generated, because of the oscillatory character of the spark-gap discharge.



WASHING MUD OUT OF A TYPE C INDUCTION MOTOR WHICH HAD BEEN UNDER WATER DURING A FLOOD

A transformer may be made to generate its own test voltage by connecting one side of both high and low-tension windings to ground and putting double voltage on the low-tension winding. This subjects the high-tension winding to a voltage varying from zero at one side to double normal voltage at the other. The connections may then be reversed and the other side tested in the same way.—*Road Section.*

EDITORIAL COMMENT

CARNEGIE GIFT TO ENGINEERING

A LETTER which promises to mark a new era in the development of American Engineering Societies was written by Mr. Andrew Carnegie on the 14th of March, addressed to the National Societies of Mechanical, Mining and Electrical Engineering and The Engineers' Club of New York. The letter contains but a single sentence, and reads as follows:

> "It will give me great pleasure to devote, say one and a half million dollars for the erection of a suitable Union Home for you all in New York City."

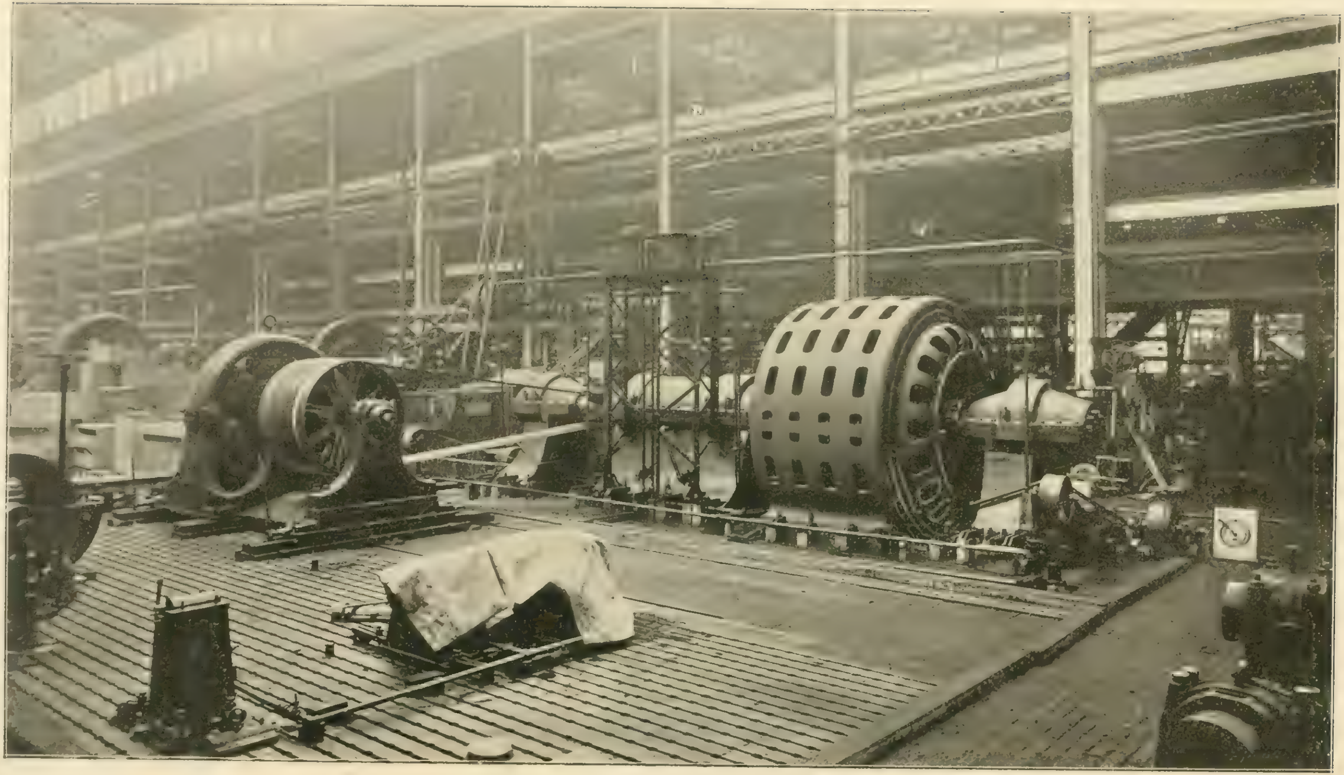
It has been generally known for about a year that Mr. Carnegie had proposed such a gift and that it originally included an additional engineering society and was for a less amount. As one of the Societies has seen fit to retain the building which it now occupies, instead of joining with the others in a new building, and as the first amount has been found inadequate the former letter has been superseded.

The Joint Committee having the matter in hand regards the gift as a trust for Engineering, to be administered not only for the Societies named, but for other societies of engineers, of which there are many which will be greatly strengthened and benefited by sharing in the use of the building. Aside from its auditorium, lecture halls, secretaries' quarters, committee rooms and the like, there will be provision for bringing together the present libraries of the Societies and making them a nucleus for a great American Engineering Library.

The space at command does not permit of an adequate expression of appreciation of Mr. Carnegie's generosity, nor of the great benefit which will result to the engineering profession from the increased facilities afforded the National Engineering Societies and the closer touch in which they will be brought through their occupancy of this common home. Mr. Carnegie has provided for both the professional and social sides of engineering life, as two abutting buildings are to be erected, one on Thirty-ninth street for the Engineering Societies, and the other on Fortieth street for The Engineers' Club.

One of the most notable characteristics of the development during the past generation has been the advance in all branches of its engineering work The next decade will undoubtedly see advancement even greater than that of the past 20 years. The Engineering Building will be a great material factor in promoting this advancement. It should be a matter of especial gratification to the members of THE ELECTRIC CLUB that one of its own number has had such an important part in the success of the undertaking. As is generally known, Mr. Charles F. Scott, Chief Electrician of the Westinghouse Electric & Manufacturing Company, was President of the American Institute of Electrical Engineers last year, and was summoned by Mr. Carnegie the day following an address at which Mr. Carnegie was present, in which Mr. Scott had spoken of the need of an engineering building. Mr. Scott has been indefatigable in his work in connection with the Engineering Building and is Chairman of the Joint Committee to which the enterprise has been entrusted.

W. M. McFarland.



THE TEST OF A 5 500 KW TURBO-GENERATOR

THE
ELECTRIC CLUB JOURNAL

Vol. I. MAY, 1904. No. 4.

THE ELECTRIC ELEVATOR.

By HENRY D. JAMES

A Lecture Before The Electric Club, January 11, 1904

THE electric elevator finds its greatest application in two classes of service: in small installations, particularly residences, where it is not desirable to have an engineer or even an elevator operator; and in buildings, such as department stores, in which the elevators are scattered over a considerable area. It is best adapted for low rises, and is seldom used where the travel exceeds 150 feet.

The flexibility and simplicity of electric power distribution and control gives the electric elevator a number of inherent advantages. The more important of these are as follows:

Where there is a central station supply of electrical power, electric elevators can be installed much cheaper than can an hydraulic plant, since the latter requires pumps and tanks in addition to the elevator machine.

In any case maintenance and operation are cheaper, since the constant attendance of an engineer is not required.

The electric elevator requires space on only one floor—and small space there. The machine and controller can readily be placed in a space six feet by ten feet. The hydraulic machine must be placed in a hatchway back of the car-shaft, or in the basement in a horizontal position.

The efficiency of the electric machine is relatively high, because of the high efficiency of the motor over its entire range of load, and because the car can be over-counterbalanced, so that the motor is only required to lift a little over one half of the total load in the car as a maximum.

The electric elevator has a very simple car-control, which does not require an expert operator. When a landing has been made, the brake on the machine holds the car rigidly until it is again started by the operator. With an hydraulic machine the car has a tendency to creep when the packing in either the cylinder or valve begins to leak. The electric elevator has a close speed regulation compared with any other type.

With an electric elevator there is no danger of interrupted service due to freezing, as in an hydraulic machine.

These advantages are to some extent balanced by disadvantages:

The usual type of electric machine has no positive limits of travel; the drum can continue turning indefinitely in either direction. To overcome this, the machine has to be provided with limit switches, which cut off the power from the motor and apply the brake.

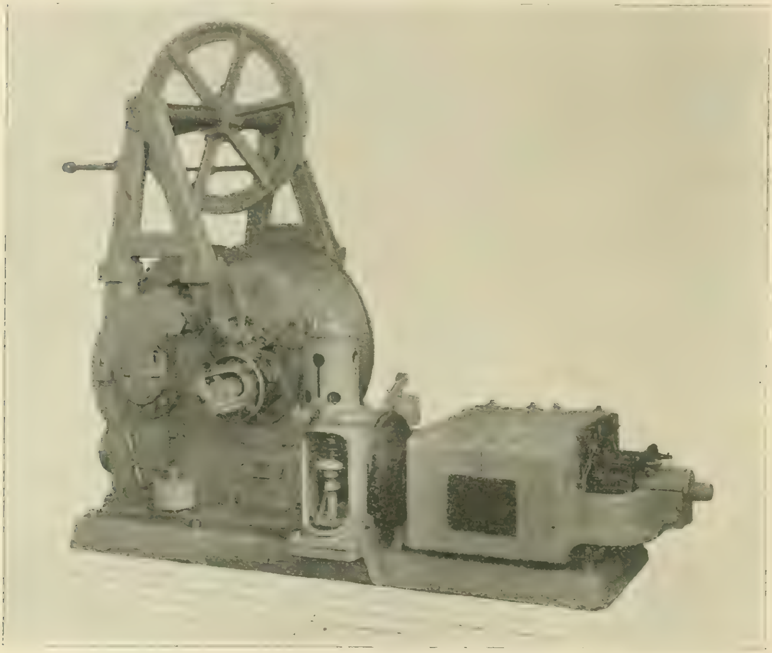


FIG. I—ELECTRIC ELEVATOR MACHINE WITH SAFETY MAGNET BRAKE

The counterbalancing system is complicated, and the counterweights sometimes cause accidents, due to the weights running into the overhead work and falling onto the car or some other portion of the machinery. Overbalancing gives the car a tendency to run away on the up-motion unless it is properly controlled.

Should the car or counterweight become obstructed in their descent, the drum will continue to unwind the ropes, which will cause them to become tangled, so that new ropes will generally be required.

Electric elevators are subject to temporary shutdown, owing to the burning out of fuses or other minor parts of the control apparatus.

The electric motor is capable of exerting several times its normal torque under certain conditions, which has caused several serious accidents. The electric machine requires the use of both a mechanical brake and a dynamic brake, whereas with an hydraulic machine the water, being practically incompressible, forms its own brake when the valve is closed.

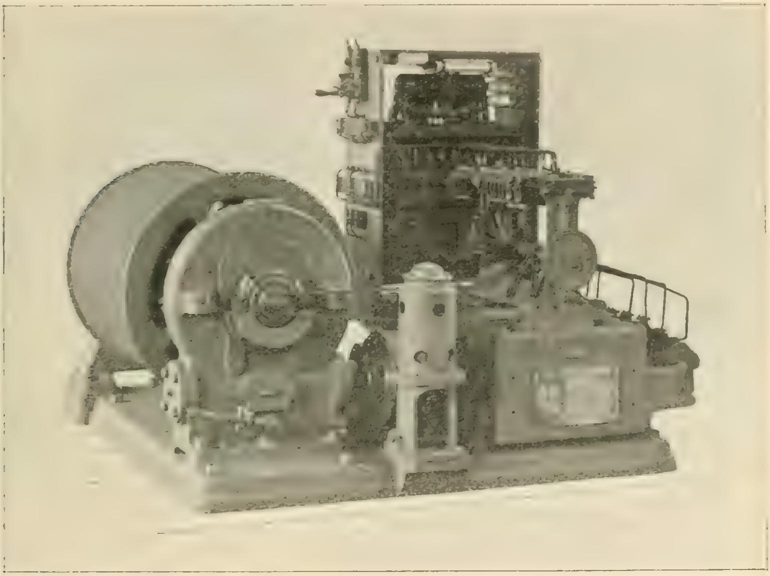


FIG. 2—AUTOMATIC HOUSE ELEVATOR MACHINE WITH PUSH BUTTON CONTROL. FRONT VIEW

The drum type of electric machine does not run quite as smoothly as the hydraulic type, and the starting and stopping is not so easily and quickly accomplished. Owing to the complicated nature of the speed control, it is not desirable to provide for more than two speeds.

The type of machine used for electric elevator work is universally a drum, driven by means of worm gearing, the motor being mounted on the worm shaft and running about 800 revolutions per minute and the drum making about twenty-five turns per minute. The end thrust of the worm on the smaller sized machine is taken up on ball-bearing, end-thrust collars; on the larger type of machines the thrust is compensated by using two worm wheels driven by right and left-hand worms in opposite directions, the worm wheels meshing together in the same manner as spur gears.

On the best class of machines the worm and worm shaft consist of a solid steel forging, and the worm gear is made of phosphor-bronze. The gear is mounted on a heavy cast-iron center, which is provided with four lugs which engage with four similar lugs cast near the periphery of the drum. Keys of every description are dispensed with for driving purposes as a matter of safety.

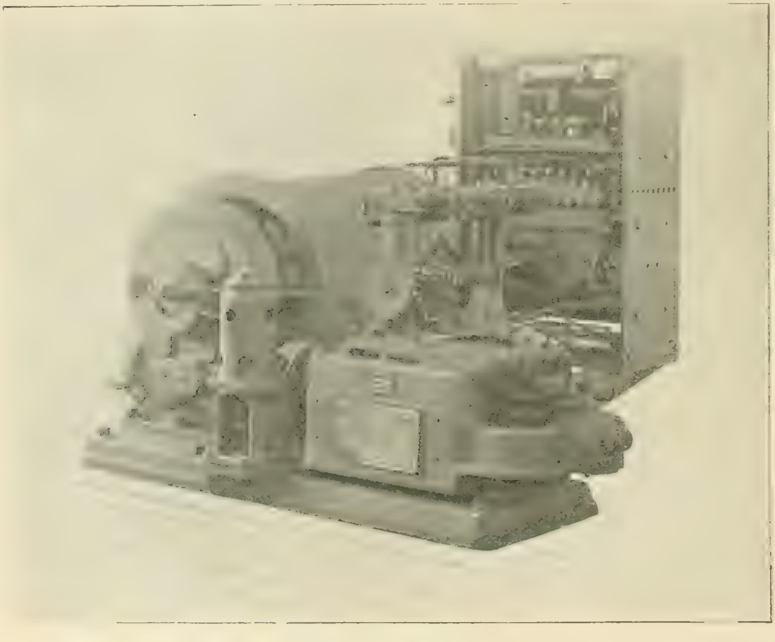


FIG. 3—AUTOMATIC HOSE ELEVATOR MACHINE WITH PUSH BUTTON CONTROL. REAR VIEW

The motor for direct-current circuits is heavier than motors of the same rating used for other purposes; it is provided with three windings—the regular shunt field, a regular series field and an extra shunt field; the series field is used for starting and the extra field both for starting and stopping, the shunt field being always connected while the motor is in operation. The armature is kept as small in diameter as possible.

The mechanical brake used with electric elevators preferably consists of a sheet-iron band lined with leather, bearing on a cast-iron pulley. The band is made in two halves, so arranged that the retardation can be adjusted separately for both the up and down motion. In addition to this brake, the motor is short-circuited through resistance, forming a dynamic brake. In the largest types of machines an additional mechanical brake is provided for emergency purposes.

The car is counterbalanced by an independent counterweight, which consists of a cast-iron weight attached by ropes to the top of the car, and balances all but a few hundred pounds of the car weight; also by a machine counterweight attached by ropes to the opposite side of the drum from the hoisting ropes, and balances the remaining car weight, together with one-half the average load; this weight is wound up as the car ropes are unwound, and vice versa.

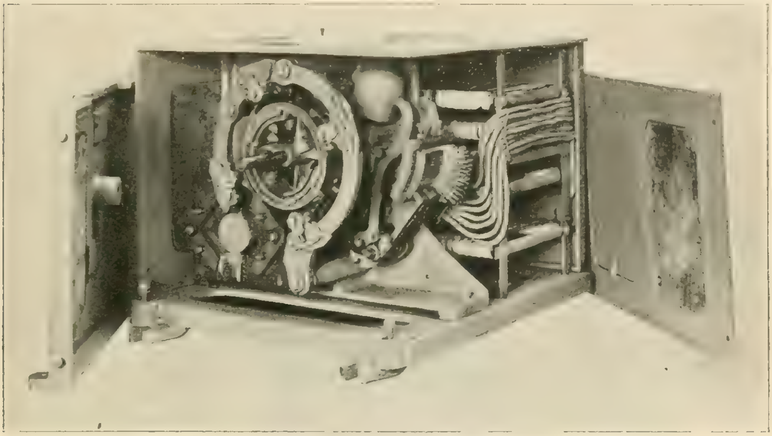


FIG. 4—CONTROLLER FOR HAND-ROPE OPERATED ELEVATOR

The hand rope is the cheapest form of controlling apparatus, but it is not used for high-speed elevators. A lever or wheel device placed in the car has been used considerably in the past, but as it is as expensive as a switch control, and is much more complicated and less satisfactory, it is, therefore, little used at present. An electric switch placed in the car is the best and most approved form of control for an elevator; it is very extensively used, and no other device should be used on a high-speed elevator. The automatic push-button control consists of a push-button placed at each floor for calling the car to that landing; the control proper is the same as the control used with a car switch, but instead of an operator being placed in the car to operate a switch, push-buttons are placed at each landing and also in the car. These buttons operate an auxiliary control system, which in turn actuates the regular control for the motor.

A good control system of any type should have the following features:

The top control should be arranged to stop the machinery at the top and bottom landings automatically and independently of the regular control system. There should be at least a duplicate set of stops both at the top and bottom landings; one, the regular stop mechanism, and one, an emergency stop, adjusted to operate a little above the top landing and a little below the bottom landing.

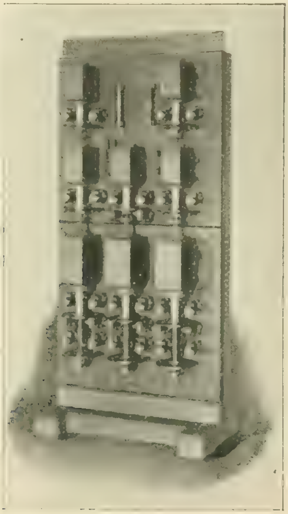


FIG. 5—MAGNET CONTROLLER OPERATED BY ELECTRIC SWITCH IN CAR

The machine should have an effective mechanical brake, and in addition to this, the motor should be arranged to operate as a generator through a short-circuit resistance to assist in bringing the car to rest.

A switch should be provided for stopping the machine should the ropes become slack from any cause.

It is desirable to have an independent stop-switch in the car, by means of which the operator can bring the car to rest should his regular operating device become disarranged.

The control should be arranged to give a practically constant speed to the car, whether the motor is operating as a motor or as a generator.

The maximum starting current should not exceed the maximum running current by more than 10 or 15 per cent. In the best controls this starting current never exceeds the maximum running current.

The control should give a smooth acceleration and retardation.

The controller should be so arranged that the motor cannot be reversed at a high speed, and all the resistance must be inserted in the armature circuit. Even should all the resistance be inserted in the armature circuit and the motor then reversed at full speed, the counter e.m.f. will be added to the line voltage, practically doubling the effective voltage at the motor terminals.

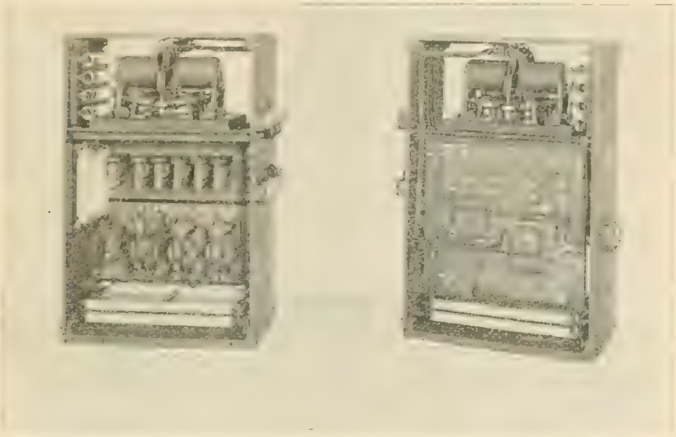


FIG. 6—PUSH BUTTON CONTROL

The main line should be broken at several different points, and all contacts should be protected by carbon brushes, but final contacts should be made copper to copper.

The controller should be arranged to return to its normal stop position, should the power at any time be cut off the supply line.

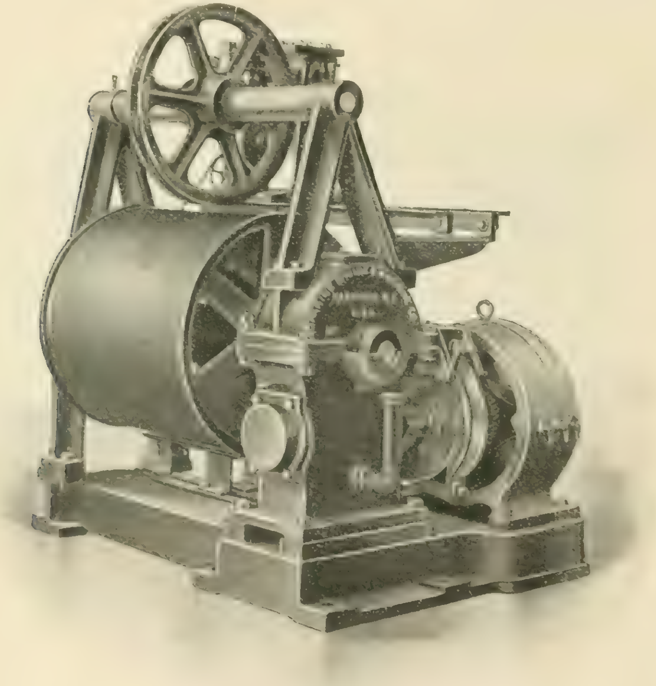
The car switch should be arranged to return to center when the operator removes his hand from the handle.

These requirements are filled at present by at least one of the commercial elevator controls.

PRESENT STATUS

The present status of the electric elevator may be summed up as follows:

The direct-current drum type machine, with the most modern method of control, gives very satisfactory results up to a speed of 300 feet per minute. The cost of maintenance of this machine is reasonable where it receives proper attention, the depreciation being less than 10 per cent.



DRUM TYPE OF ELECTRIC ELEVATOR MACHINE

Direct electric machines of other types, which have been designed to compete directly with the higher speed hydraulic elevators, have not yet come into general use. These machines are too complicated in control and design, too expensive to buy and maintain, and some types have not yet proved that they are entirely reliable in their action. A large number of direct-current electric machines have been built for speeds of 500 and 600 feet a minute, and are to-day in successful operation, but they have not so far gained the confidence of the public at large nor the unanimous confidence of elevator engineers.

Direct-current electric furnace hoists up to 300 horse power have been built and installed to run up an inclined plane 300 or 400 feet a minute with large loads, and stop automatically at the top and the bottom. These machines have been in operation for several years and are entirely satisfactory. Their cost, however, is greater than for steam furnace hoists, and for this reason they are not as extensively used as their satisfactory operation warrants.

FUTURE DEVELOPMENTS

The future developments in electric elevators may be expected to be along the following lines:

The drum type of electric machine probably will not be used for speeds above those for which it is now built; in fact the tendency of the last few years has been to decrease the speed of this machine, as it has a number of inherent defects when used at higher speeds.

High-speed electric elevators will probably be developed in the future when the demand for such elevators is sufficient to force the matter upon the elevator companies. Engineers have been working on this type of machine for a good many years, and there are a number of experimental plants installed which give promise of some success in this direction; however, the entire satisfaction given by the present hydraulic elevator in this class of work has not rendered the development of this electric elevator an absolute necessity. In a number of instances where it has been desirable to use electric power for elevator service, hydraulic elevators have been installed and water power developed by means of pumps driven by electric motors.

Alternating current is used as a source of power for slow-speed electric elevators. The difficulties which have prevented the general use of the induction motor for high-speed elevators are as follows:

It has been difficult to make an accurate and reliable automatic stop at the top and bottom landings owing to the fact that the commercial motors were essentially one-speed machines.

Owing to the fact that the characteristics of the induction

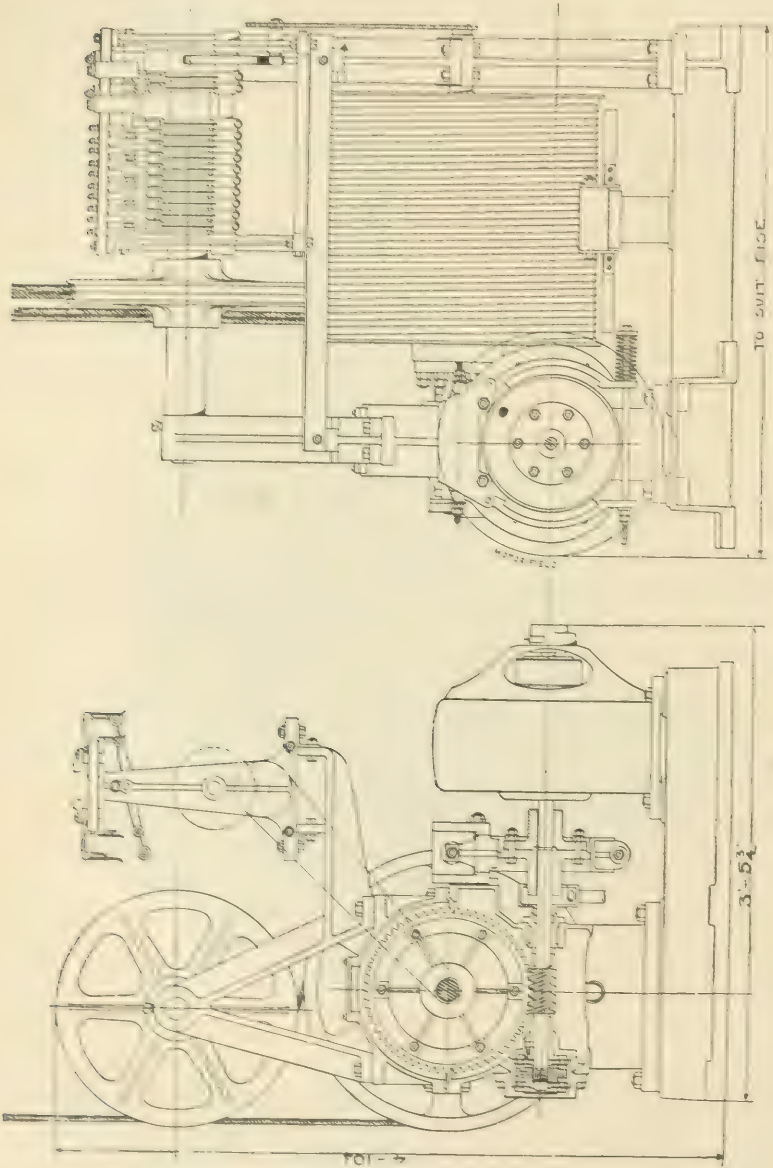


FIG. 8—ELEVATIONS OF DRUM TYPE MACHINE

motor are similar to those of the direct-current shunt motor, it takes considerably more starting current than maximum running current even when resistance is inserted in the secondary.

Up to the present time all commercial controls are of the simple rheostat type where the speed of the motor is controlled entirely by inserting resistance in series with either primary or secondary; or the primary voltage is reduced by means of auto-transformers.

The rotor of the induction motor is large and the fly-wheel effect makes it difficult to stop. Where the direct-current motor is used it is generally made with an armature as small in diameter as is practicable.

The most promising field at present for the induction motor in elevator work seems to be in connection with hydraulic installations, where the induction motor is used to drive a centrifugal pump. No installations using the centrifugal pump have yet been made, but the matter is in such shape that there probably will be several of them in operation shortly. These motors are being used with success to operate triplex pumps by allowing the motor to run constantly and by-passing the pump automatically when the pressure reaches the desired point.

THE YOUNG ENGINEER AND HIS OPPORTUNITY

By CHARLES F. SCOTT

Major Portion of an Address to the Graduating Class, 1903, Stevens Institute of Technology

A SIGNIFICANT condition exists in the field of technical education. Scientific and engineering courses, both in schools of technology and in universities, mark the great evolution in modern education. Although the facilities for this new kind of education are constantly increasing and expanding, yet the number of students increases faster than funds and equipment. Notwithstanding this, graduating classes of increasing size are insufficient to meet the demands for technically educated young men.

What are the conditions which have placed a premium upon graduates in engineering and have opened new opportunities to the younger engineer? A general view of the situation is contained in a letter which I recently received from an engineer whose wavy, though distinct, writing marks him as well past the meridian of life, and which contains these sentences: "At the Philadelphia Centennial, 27 years ago, we were all asking, 'What will the next 100 years witness?' It has witnessed already more for science, engineering and humanity than all that has been accomplished before, and is now in the throes of yet greater things, which it is developing with yet greater energy."

We who are younger have become so accustomed to accelerating progress that we do not have the perspective by which we may appreciate the change which has taken place. But a new era has come. We live in a new civilization. It is the result in no small degree of scientific discovery and its application. I will not recount the steps which mark the evolution of the past century, nor will I indicate precisely how "the engineer, one skilled in the application of materials and forces of nature to the use of man," has been a prime factor in the evolution from savagery to civilization. The change from the stage coach to the express train, the hackney coach to the electric car, the shoemaker's bench to the great factory, are illustrated and typical of the new order of things. Find, if you can, a single important material element in your daily life which has not in some way been vitally affected by the work of the engineer. The books we read, the food we eat, the clothes we wear, the houses we live in, our methods of heating, of lighting, of water supply, of travel, of communication, have all been transformed since the days of our fathers.

It would be interesting to consider in detail the specific ways in which the development of different phases of engineering work have been effective in accomplishing useful ends. It is of interest also to generalize in order to determine the particular process, if such we may call it, by which engineering promotes progress. Consider first the methods by which the newest branch of engineering has become so effective. The result of the application of electricity may be summarized by saying, Electricity increases efficiency. The electric motor, for example, does little which may not be done by other means, but it propels cars, it operates cranes, it drives machine tools and printing presses more conveniently, or rapidly, or cheaply—in short, more effectively, than other agents. By reducing time and cost and increasing output, it increases efficiency. In the same manner the great result of engineering is this, *Engineering increases efficiency*. It provides the instruments and the means and the methods by which the results of human activity are enormously increased. It increases the work a man can do; it increases the wealth a nation can produce; it increases comfort and well-being it gives larger and broader life. The building of a new bridge, or of a larger or more efficient engine, or of a more convenient office building, are not merely individual things to contribute to the convenience of a few persons; still less are they to be considered merely as the means by which the engineer or the builder may derive remuneration. They are part and parcel of the great mechanism, of the intricate machinery of our modern life, and they are as essential to its existence and its prosperity as are the buildings and power plant and tools in a great machine shop to the workmen who are making locomotives. Consider it in this light, young men, and the profession you have chosen is one whose calling is high and whose responsibilities are large. Do not lose sight of this broader view; do not become so absorbed in minutiae or in details that you miss the inspiration which comes from realizing the part which your profession and your work are to fulfil in promoting onward progress, for we are now "in the throes of yet greater things."

A recent experience has particularly impressed me with the new rate of acceleration of the times in which we live. I have been privileged to visit Oxford's classic halls and to walk across the greens of Cambridge and beneath the line of overhanging limes. It is a wondrous presence—to visit these nurseries wherein for centuries the flower of England's strength has been nurtured and the thoughts and the ambitions which have made Anglo-Saxon greatness have had their birth.

To me there was one thought pre-eminent, even to me, who spent his early years in an old university, the oldest in the Northwest territory—it was the pervading sense of the ancient, the unchanged. Here were buildings dating back beyond the days of Columbus' voyage, here were halls and cathedrals bearing the insignia of kings and queens and heroes of England's history so far back that history almost merges into myth. Yet it all stands to-day as it might have stood then. One can imagine that Addison has just preceded us along the walk which inherits his name, or that Newton has just entered the door which has been indicated by the friendly Baedacker. The past is preserved, one sees scarcely an anachronism. Outside the walls there may be an occasional tram car, or the electric light may dispel the old-time darkness, and down this little street with its peculiar turns and curves there are laboratory windows where the sight of test tubes and of dynamos may jar upon one's classic musings, but they are so exceptional that they are like the glimmering candle that intensifies the gloom. Pass on a square, enter another portal and there is nothing to dispel the dream that you have been transported back for half a thousand years.

If I return to my native Ohio and visit the institution nearly a century old at Athens and then my younger alma mater at its capitol city, I do not feel at home; they are not familiar, for in buildings and facilities and faculty and students they have more than doubled; they have twice doubled since I, who still count myself a young man, stood upon the campus on a beautiful June day to receive a diploma. The advance which a decade now records is greater than that in centuries of the past. Let us beware lest the thoroughness and the strength of the old, enduring plan, with all its charm which softens life, are not lost in the new methods of the strenuous present.

You are going forth to take up your part in the world's work at a time when the work of the engineer *per se* has attained new magnitude, new importance and a higher rate of advancement. It is at a time also when social and industrial affairs are in the midst of great changes, and at a time when the work of the engineer is most fundamentally and intimately related to these great movements. The very conditions which underlie modern life, such as railroads, steamships, manufactories, power transmission, the construction of modern cities with concentrated, intensive social and business activity—all these come from the engineer. Modern co-operation, social, industrial, commercial, financial, are all the outcome, the results of the conditions which have been forming and crystalizing as the results of engineering work. Hence, the wider range, the greater responsibilities, the larger life of the present and the coming engineer.

One of the important phases of the new order of things is the aggregation and combination of industries and of capital which characterizes every branch of business. It has been asserted that this is subversive of individual independence, that it restricts individual aspiration and advancement, that it is a dark cloud on the horizon of the college graduate.

I have seen recently an extract from an address by Mr. James B. Dill, at the University of Minnesota, which deals with this question. He said: "I believe that the tendency to organization, to combination, has put a demand on the college trained minds, has put a premium upon the services of such men and has made it easier than formerly for the college graduate to get started and to succeed in the world. When the trust movement shall have steadied itself, and when it shall have eradicated those tendencies which are, apparently, in the wrong direction, when it shall have increased and strengthened those elements which are right, then the men in charge of the great combinations and in executive positions will be the men who not only have a knowledge of the business, but whose minds have been broadly trained and whose characters have been formed within university halls. The situation demands the employment of college men."

There is another aspect of the modern movement in which the tendencies are not so clear. We know that civilization and co-operation go hand in hand. We recognize the fundamental economies which are the inspiration and the justification of the corporation as a financial and industrial institution. It is coming to be generally believed that in so far as its financial and commercial and engineering aspects are concerned, the trust is sound in theory, and that if it fail it is not because of wrong principle, but through misuse and abuse of that principle. But there is an element in the problem aside from that of finance, aside from that of engineering and of production; it is the human problem—the problem of the relations between men. I apprehend that there is a general feeling that the large corporation is not theoretically sound from the social standpoint, that although it may lead to economies in production, it does not conduce to general individual advancement and personal freedom. It is felt that the tendency is to elevate a few leaders and to group men into masses and to treat them in the aggregate and not as individuals.

As engineers, our training and experience teaches us that what is correct and sound in principle may, with favoring conditions and skill, be made successful in practice, and also that what is in principle unsound must sooner or later make way for something new. It is fitting, therefore, that we should first determine what is the correct principle, the ideal thing in the movement toward combination, and then work toward that ideal.

Let me quote in this connection from an address upon "Man-Power," recently delivered before a club of young engineers in a manufacturing company by Mr. T. C. Frenyear:

"What is the true principle of organization in a democratic community? Is is this: Getting others to do what you want done, while they are doing what they themselves wish to do; inspiring others with a desire to do what you want done, not driving them to do it. * * * The true master of men appeals to the high motives and aspirations; creates an atmosphere which awakens and inspires; is big, bold, powerful, and attracts and attaches to himself the wills of his men. Forces, things, men, are all the raw material out of which he builds vast structures, using each according to its fitness for his plan, but without violating either the law of matter or the individuality and freedom of man."

Such sentiments as these which I have quoted put a new meaning into the movement toward organization and combination. These general questions are not separate and apart from the field of the engineer. They are vitally connected with his work and his interests. He who has paved the way by the development of material things for combination in financial and commercial and industrial affairs, which in turn have led to new social problems, has assumed new relationships and new responsibilities. He has furnished the machinery and the material appliances and facilities on which the great interests of the present are based. May not the methods and the principles and ideals which have proved successful in dealing with material things be applied also to those organizations which deal with men? Has not this material basis of modern life been more successfully and skillfully and completely established than its financial and political and social relationships? It is unjust distribution of wealth and speculation, it is corruption in municipal and general government, it is conflict between laborer and employer that disturb and threaten. The engineer is in contact with facts; he has learned the value of Truth. He knows and he respects physical laws. Effects follow causes quickly; failure is the certain consequence of false data or bad methods. But human affairs are more complex; failure cannot be so readily traced to its cause, the Truth is not so evident, nor is it so respected, yet after a longer time it is just as surely final. The ideal underlying engineering work is efficiency—the production of the maximum result with the minimum of effort. The prevailing motive elsewhere is selfishness. Trace them back to their ultimate causes and you will find that the real danger in business is that which comes from greed, and the real cause which underlies the conflict between labor and capital is selfishness. The aim of the old-time military engineer was destruction; the object of the modern engineer is construction. Engineering became a new factor in world history when it severed itself from warfare. Who can picture the transformation when the principle of war and selfishness in business and in social affairs shall be supplanted by higher and nobler and better motives? Then we shall find that the Golden Rule—the law of Love and the law of Efficiency are one and the same.

To you who are about to step forth from your Alma Mater there opens a marvelous opportunity. The work of the engineer has deepened and broadened, and he who will secure the highest results is he who combines in himself the essential elements of leadership in many fields.

I repeat, the underlying material basis of the past century's progress and of present prosperity, of the evolution in commercial and industrial and social conditions, of modern co-operation, is engineering. But not only has engineering work made them possible by giving them a material basis, but the modern corporation should be operated upon engineering methods, and modern society should have as its ideal the engineering principle of efficiency. Economy alone justifies the modern business corporation—every one of them needs engineers to lay the foundations for economy of production or of operation. The future calls for engineering work greater in amount and higher in kind, it calls also for engineering methods and engineering ideals, it calls for men who can build bridges and engines and cities, it calls for men who can direct human as well as physical forces, it calls for men of strong character, inspired by high ideals, who can transform modern life by engineering principles as well as by engineering practice, and by so doing embody in our commercial and political and social life the simple principle of efficiency.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

II.—ELEMENTARY EXAMPLES—(CONTINUED)

By V. KARAPETOFF

A Series of Lectures Delivered Before The Electric Club, October-December, 1903

CONNECTION OF RESISTANCE IN PARALLEL

An ohmic resistance r and an inductive resistance x are connected parallel between the points A and B of the circuit Fig. 15 It is required to find the relation between the total current I, the component currents in r and x and the e.m.f. between the points A and B.

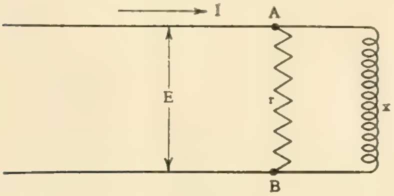


FIG. 15

First, suppose that this e.m.f. is given (Fig. 16). The current Ir in r coincides in phase with this e.m.f. and is equal to $E \div r$. The current Ix in x is equal to $E \div x$ and lags 90 degrees, as is shown in the diagram. The total current I in the line is equal to the geometrical sum of both currents and is represented in its magnitude and phase relation by the diagonal of the rectangle having Ix and Ix as its sides. If the total current I is given and the e.m.f. is unknown, assume an arbitrary value E_1 and construct the diagram Fig. 16. This will give a value I_1. Then reduce the assumed voltage in the ratio $I:I_1$ to get the true voltage.

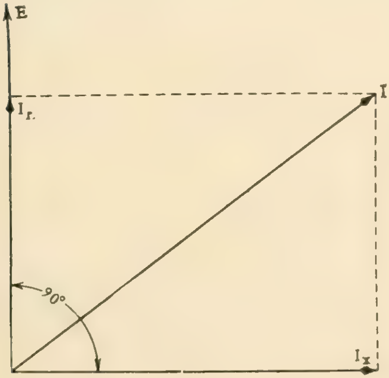


FIG. 16

Induction Load for an Alternator—A 100-kw single-phase alternator for 1 000 volts pressure and 100 amperes full-load current has to be tested under full-load conditions at 70 per cent. power-factor. It is required to find the values of the ohmic and inductive resistance to be provided for such a test.

First, assume these resistances to be connected in parallel, so as to take separately the working and the wattless component of the current. Let $OA=E$, Fig. 17, represent the e.m.f. of the machine, and $OB=I$, the vector of its current drawn at an angle corresponding to the power-factor 70 per cent. (see triangle *OCD*). By completing the triangle *OBL* the working component of the current is found to be $OL=70$ amperes and the wattless component $BL=71.5$ amperes. Accordingly, the ohmic rheostat has to be about 1 000 : 70=14.3 ohms and the choke coil (inductive resistance) 1 000÷71.5=14 ohms.

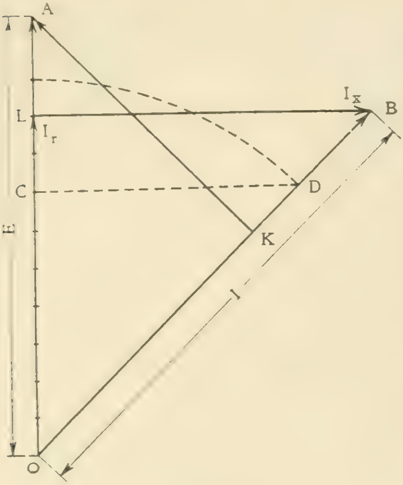


FIG. 17

Now determine the values of the resistance for the same test under the supposition that the choke coil and the rheostat shall be connected in series. The same diagram, Fig. 17, can be used; except that instead of a triangle of currents, a triangle of the component e.m.f.'s is used. Drop a perpendicular *AK* on the current line and obtain the triangle *OAK*. Its sides being measured are equal to 700 volts and 715 volts. Consequently the ohmic resistance has to be in this case 700÷100=7 ohms and the inductive 715÷100=7.15 ohms. According to local conditions and the apparatus at hand, the one or the other scheme of connections may be more convenient.

Series Incandescent Lamps—For lighting long canal series incandescent lamps are used, each shunted by choke coil to prevent the circuit being broken by the burning out of the lamp (Fig. 18). The total current in the line consists of a working component flowing through the lamps and a wattless component flowing through the choke coils. After one or more lamps have burned out, the total current must flow through the corresponding choke coils, so that the tension at the terminals of the machine must be somewhat increased to keep the same value of current through the remainder of the lamps. But if the number of lamps in series is considerable and the inductive resistance of the choke coils is appropriately selected, burning out of few lamps will have practically no influence upon the brightness of other lamps; it may be said that this system combines the advantage of the series connection (great reduction of line copper) with the independence of each lamp, as in the parallel connection. We shall construct the diagram for the two conditions:

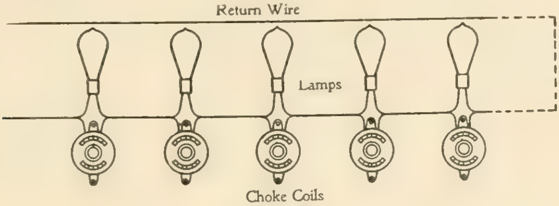


FIG. 18

(1) While all the lamps are burning.

(2) After 25 per cent. of the lamps are burned out.

Let the line consist of 100 lamps for 50 volts and 3 amperes each, and the inductive resistance of each coil be 21.8 ohms, so that it takes under normal condition a wattless current of $50 \div 21.8 = 2.3$ amperes Let *AB*, Fig. 19, represent the total voltage $100 \times 50 = 5000$ volts and *AC* and *AD* the working and the wattless components of the current. *AF* is the total current in

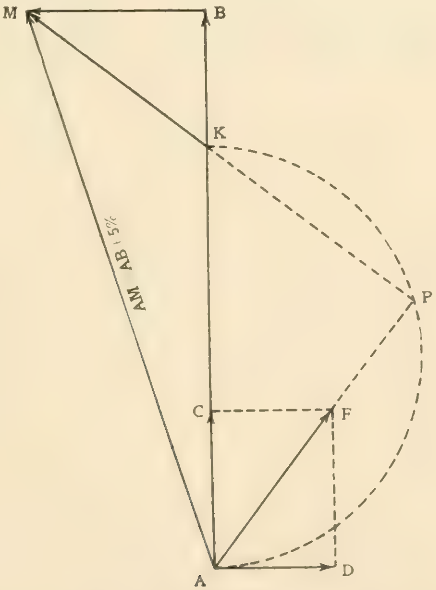


FIG. 19

the line, and as measured on the diagram is equal to 3.78 amperes. The ratio, $AC:AF=80$ per cent., is the power-factor. Now suppose 25 per cent. of the lamps burn out and the tension at the machine terminals to be increased to give the same total current, 3.78 amperes. The total tension at the terminals of 75 per cent. of the lamps is now $AK=0.75\ AB$. The voltage at the terminals of the remaining 25 per cent. choke coils, which carry the total current, is KM instead of KB, where ratio $KM:KB$ is equal to $AF:CF$ (because the current in these choke coils is increased from CF to AF). KM is perpendicular to AF, because the choke coils have only inductive resistance, and the voltage at their terminals must lead the current by 90 degrees. The resultant e.m.f. of the generator is $AM=AK+KM$ (geometrical addition). The diagram shows that the voltage AM is only 5 per cent. higher than AB, that is, burning out 25 per cent. of the lamps demands only 5 per cent. increase of voltage at the generator. The same problem can be put inversely: to find such a value of inductive resistance of the choke coils that a regulation of but 5 per cent. be necessary after 25 per cent. of the lamps be burned out. In this case the diagram must be constructed beginning with the triangle AMB, where $AB=5\,000$ volts and $AM=5\,250$ volts. Then the circle APK and the line MP can be drawn, after which the direction of the total current vector AP will be determined. Then draw CF, which gives the wattless component, 2.3 amperes. Dividing 50 volts by 2.3 the inductive resistance of the choke coils is found to be 21.8 ohms.

This series arrangement has great advantages for lighting long distances where but small illumination is needed, as lighting canals, yard track, small railway stations, highways near cities and so on. A close regulation of the voltage is not necessary in such cases, and slight differences in the amount of light given by a lamp would not be noticeable.

SERIES-PARALLEL CONNECTION OF RESISTANCES

An ohmic resistance, r_1, and an inductive resistance, x_1, are connected in series Fig. 20. Two other resistances, r_2 and x_2, are also connected in series, and both groups are connected in parallel. It is required to find the relation between the voltages and the currents in both branches Fig. 21.

Let *CD* be the voltage between the points *A* and *B* Fig. 20. Triangle *CDF* gives the component voltages for branch (1) and *CDG* those for branch (2). The meaning of each vector is shown on the diagram. The currents $I_1=DP_1$ and $I_2=DP_2$ are in phase with the corresponding ohmic components. The total current, $DT=I$, in the line is their geometrical sum. The two triangles of voltages and the parallelogram of the currents gives full information concerning the circuit under consideration.

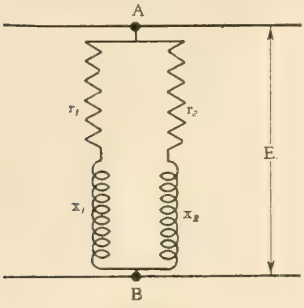


FIG. 20

If the total voltage $E=CD$ and the values of resistances are given but the currents are unknown, the diagram can be constucted as follows: Describe a half circle with *CD* as a diameter. Put $Da=r_1$ and $ab=x_1$ on any scale whatever; point *b* lies on *DF*, and triangle *DFC* can be constucted. In the same way construct triangle **D***cd* and *DGC*. Measure *DF* and *DG* in the same scale as *CD*; this will give the ohmic drop, which, divided by the corresponding ohmic resistances, determines the componnent currents I_1 and I^2 after this their resultant *I* can be easily found. Here, as in all cases, the scale of amperes is independent of the scale of votes.

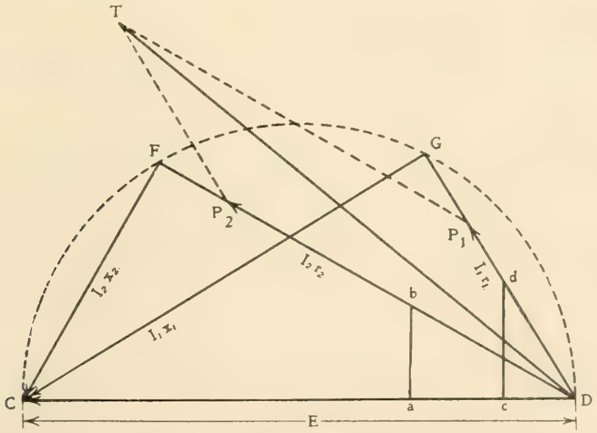


FIG. 21

If the total current *I* is given and the voltage *CD* is unknown, assume any value whatever for this voltage and construct the same diagram (Fig. 21). Suppose the resultant current to be I_1; then the true voltage E is $E_1 \frac{I}{I_1}$ and the whole diagram is to be reduced in the same ratio $\frac{I}{I_1}$.

Transmission Line Supplying Lamps and Motors—A transmission line supplies current to 200 kw of incandescent lamp load and to 100 kw load of motors having an average power-facor of 80 per cent. It is required to find the combined (equivalent) power-factor of the total load Fig. 22,.

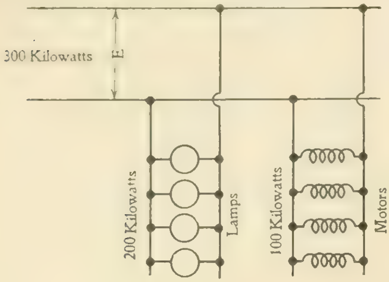


FIG. 22

Draw OA proportional to 200 kw Fig. 23, in phase with the e.m.f. (non-inductive load) and OB such that its projection OC on OA (working component) be proportional to 100 kw. The angle will correspond to the power-factor 80 per cent. Vectors OA and OB are proportional to the currents flowing in the lamps and in the motor circuits. Their resultant OF has a projection on E equal to 300 kw. The resultant power-factor affecting the generator and the line is given by the angle AOF, and its *cosine* is equal to 97 per cent., as measured on the diagram.

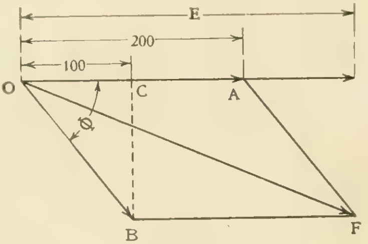


FIG. 23

Resistances Connected to Obtain Quadrature e.m.f.'s—A combination of ohmic and inductive resistances is connected across a line AB, as shown in Fig. 24. It is essential in this combination that r be connected to B and x to A in one branch and x to B and r to A in the other as shown. The problem is to find the voltage between the points K and L.

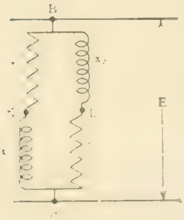


FIG. 24

The diagram is represented in Fig. 25. Triangles of voltages CDF_1 and CDF_2 are constructed in the same way as in Fig. 21. The voltage between points K and L is the difference between the voltage drop in r_1 and x_2. Therefore, from the end of DF, representing the voltage in R_1, draw a line FM, equal and opposite to $F_2C = I_2x_2$. The resultant vector DM represents the required voltage between the points K and L.

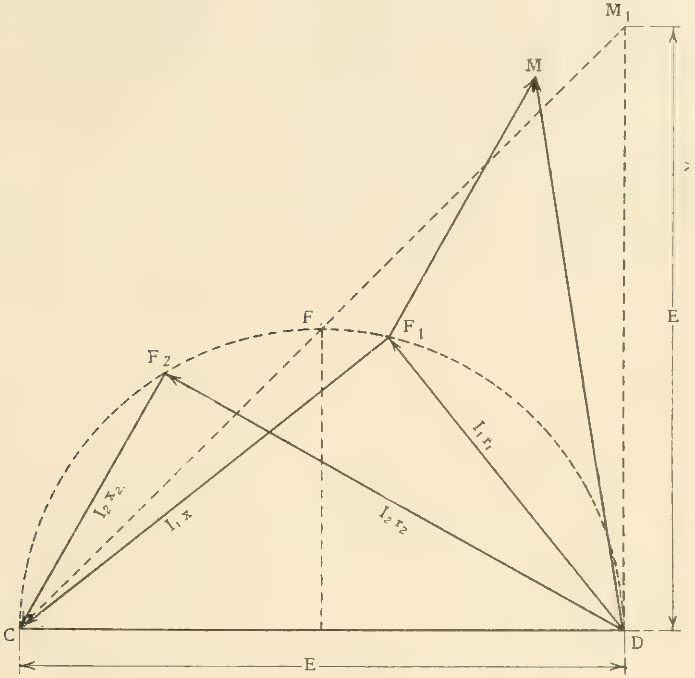


FIG. 25

The easiest way to understand why the voltage between K and L is the difference betweeen I_1r_1 and I_2x_2 is to substitute direct current for alternating current. In this case it is clear that if a voltmeter measures 30 volts between K and B and 20 volts between L and B, it will show 10 volts between K and L. To make it still clearer, suppose that point B is grounded; that is, kept at zero potential. The potential of K is in this case 30 volts, the potential of L, 20 volts; it is, therefore, self-evident that the difference of potential between K and L must be 10 volts. As a general rule, that which is true algebraically for a direct-current system is true geometrically for alternating-current vectors. Thus the pressure between K and L is equal to the geometrical difference between vectors DF_1 and CF_2.

In the special case of $DF_1 = CF_1 = DF_2 = CF_2$; that is, the four resistances being equal, this diagram shows that the voltage between the points K and L is equal to the given e.m.f. E, and lags 90 degrees behind it (shown by dotted line in Fig. 25).

This way of producing an artificial phase at an angle of 90 degrees to the fundamental voltage has been used to some extent in connection with induction wattmeters. Instead of inserting a high inductive resistance in series with the shunt winding of the meter, the above described combination of high resistances is inserted between the mains and the shunt winding of the meter is connected between the points *K* and *L*. In this way the current in the shunt winding is made to lag 90 degrees behind the e.m.f. of the current, as is necessary for producing the rotating magnetic flux. Of course, any attempt to take a considerable current between the points *K* and *L* would very much diminish the voltage between these points and also diminish the phase angle between *CD* and *DM*.

Correction for Losses in Diagram of Choke Coils—In all the problems considered it has been supposed that the inductive resistance was constant; in reality we have in almost all cases to deal with iron in choke coils, which causes the inductive resistance to vary, its value depending on the magnetizing current, or indirectly, on the voltage at the terminals. The necessary correction in the vector diagrams can be easily made if a curve be given, showing the change of magnetic permeability of the iron used with the flux density of the core, or, which is the same, showing inductive resistance of the coil as a function of its terminal pressure. In addition, the ohmic resistance of the coil cannot be neglected in all cases; sometimes a coil should be considered as an inductive resistance and an ohmic resistance in series. In addition to this, if a very close approximation be needed, iron losses of the coil should be taken into account. The easiest way to do this is to assume the coil shunted by an imaginary ohmic resistance *R* such that the loss in it be equal to the iron loss of the coil. A curve giving the iron loss of the coil as a function of the pressure *E* at its terminals must be known in order that this correction can be made. The imaginary resistance *R* is, of course, somewhat variable with *E*.

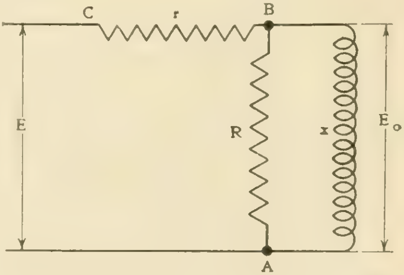


FIG. 26

Thus an actual choke coil can be replaced by the following combination of resistances Fig. 26:

(a) Actual inductive resistance x.

(b) Ohmic resistance of the winding r.

(c) Fictitious high ohmic resistance R shunted across x and representing the iron loss in the coil.

The diagram for this circuit is shown in Fig. 27.

The voltage across *AB* Fig. 26 is represented by E°. In phase with this is the energy current *Ir* in the non-inductive resistance representing the iron loss. Lagging 90 degrees behind E_0 is the magnetizing current *Ix*, flowing in the coil x. The total current I is the resultant of *Ir* and *Ix,* as shown. This total current causes an ohmic drop, *Ir,* whose vector is parallel with the current I. Then the total voltage E is the resultant of E_0 and *Ir.* It will be seen that both corrections have caused a decrease in the angle between total current and total voltage.

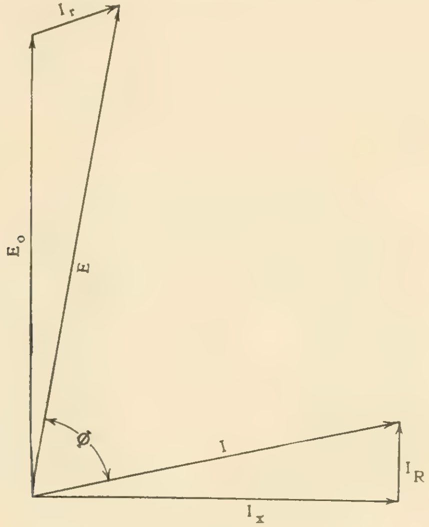


FIG. 27

Correction—On page 166, line 18, of the April issue the numerical statement should be changed to read as follows:

$250 \div \sqrt{3} = 144.5$ volts. The inductive drop is:

$\sqrt{144.5^2 - (0.35 \times 100)^2} = 140$ volts.

WINDING A RAILWAY MOTOR ARMATURE

By H. D. ROBERTSON

THE completed generator or motor armature, with its apparently complicated arrangement of coils and connecting wires, gives very little idea of what the construction of the armature really is. It is the purpose of this article to explain this by describing the construction of an armature by following it through its different processes of manufacture. The Westinghouse No. 12 A railway motor armature will be described, as this has a typical winding, and the completed armature is familiar to a large number of those who will be interested in this article.

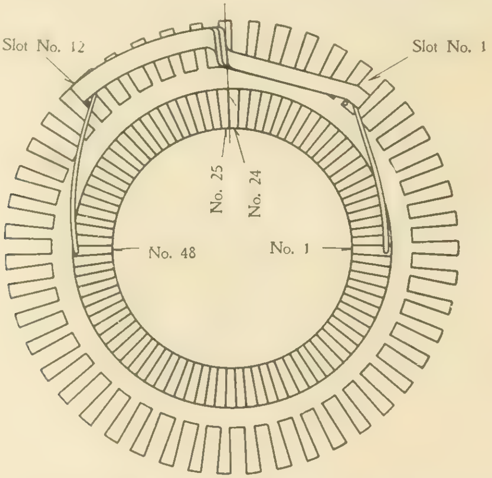


FIG. 1 POSITION OF FIRST COIL ON CORE

DESCRIPTION OF THE NO. 12 A WINDING

The Coils.—The No. 12 A armature has 47 slots in which are placed 47 complete coils, i. e., two sides of two different coils are placed in each slot; this arrangement is commonly called "two coils per slot." The "throw" of the coil is 1 and 12, i. e., one side of a coil is placed in the bottom of slot No. 1 and the other side of this same coil is placed in the top of slot No. 12. This is shown in Fig. 1. Each complete coil consists of two parts or single coils assembled together in one insulating cell. The single coil consists of five turns wound continuously with a single wire. There are therefore two leads from each side of the complete coil.

Connections of the Winding—For showing the connections of the winding the single coil may be considered as made of a single turn; the number of turns in the single coil does not affect the connections between coils or the connections to the commutator. Then considering each side of a single coil to be one conductor, there will be four conductors per slot, or 47×4=188 total conductors. One single coil, however, is disconnected from the total winding, so that there are 186 active conductors in the winding. One coil is cut out in this way, so that the winding will not form a closed circuit at the finish of the first passage around the core.

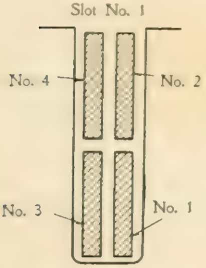


FIG. 2—ARRANGEMENT OF CONDUCTORS IN THE SLOT

In order to show the connections of the winding it is first necessary to distinguish the different conductors in a slot as in Fig. 2, and to find the "back pitch" and "front pitch" of the winding. The back pitch is the number of conductors between the two sides of the single coil. It is therefore determined by the throw of the coil and the arrangement of the wires in the coil.

In Fig. 1 the four single coils in slot No. 12 will be Nos. 45, 46, 47, and 48; conductors Nos. 1 and 46 are the two sides of the same single coil, so that the back pitch is 46—1=45. The average of the front and back pitches is given by the formula:

$$\text{Average pitch}=\frac{\text{No. conductors}+2}{\text{no poles}}$$

In the 12 A armature this is:

$$\text{Average pitch}=\frac{186+2}{4}=47$$

The average pitch being 47 and the back pitch 45, the front pitch must be 49. The front pitch is the number of conductors between the two coils connected together by the commutator leads.

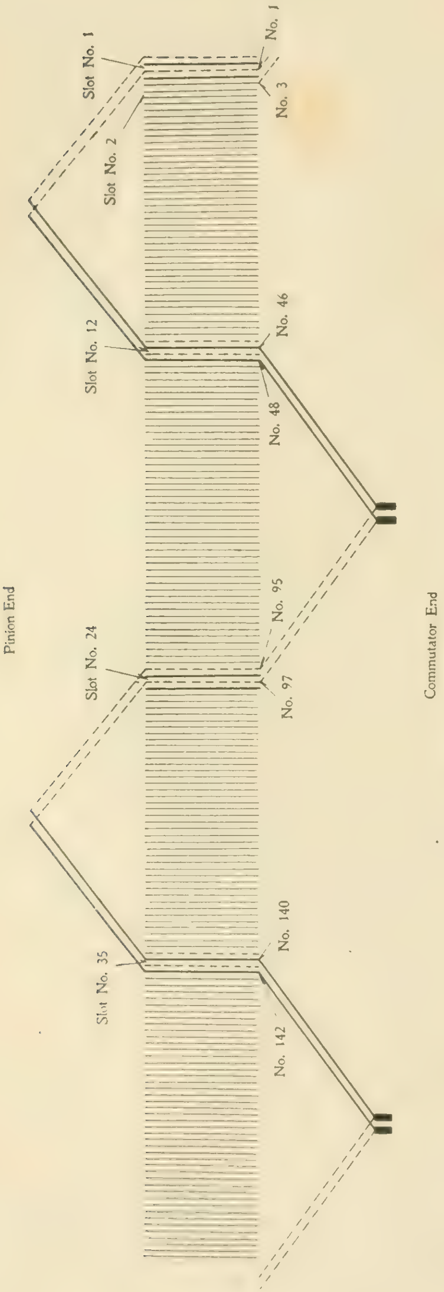


FIG. 3—CONNECTIONS OF THE WINDING

Conductor No. 1 in the bottom of slot No. 1 is connected, by the wires inside the coil on the pinion end of the armature, to conductor No. 46 (1+45), which is in the top of slot No. 12. This conductor is connected by means of the lead wires of the coils on the commutator end of the armature, and through a commutator bar, to conductor No. 95 (46+49), which is in the bottom of slot No. 24. Conductor No. 95 is connected through the coil on the rear to conductor No. 140 (95+45), which is in the top of slot No. 35, and this in turn is connected by the commutator leads to conductor No. 189 (140+49), which is in the bottom of slot No. 1, i. e., conductor No. 189 is conductor No. 3, since there are only 186 conductors in the winding.

These connections of the winding are shown in Fig. 3. When one passage around the armature circumference is completed the second passage begins with the lower conductor adjacent to the beginning conductor of the first passage; and the third passage begins with the lower conductor adjacent to the beginning conductor of the second passage, and so on until the entire armature core has been covered.

CONSTRUCTION OF THE ARMATURE

The Core—The first operation in the construction of the armature is building the core. It is built up on the shaft of sheet steel punchings which are firmly clamped between two cast iron end plates. The slots are filed sufficiently to remove any projecting edges of the laminations that would cut the insulation of the coils. The coils are prepared for winding the core as shown in Fig. 4. The side of the coil that goes in the bottom of the slot is shorter than the side that goes in the top of the slot. The leads from the short side are bent down and out and the leads from the long side are bent up and back, as shown in the photograph.

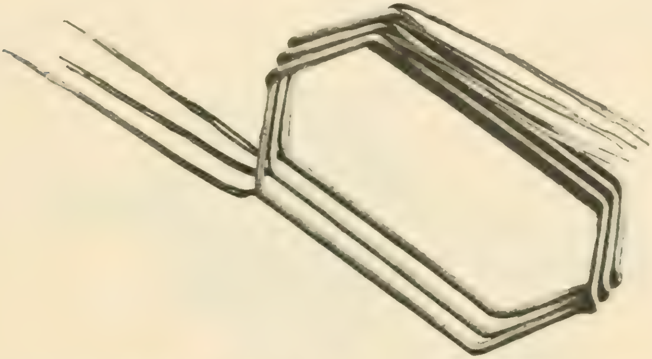


FIG. 4—ARMATURE COILS READY FOR WINDING

Winding—The armature core is placed in a winding lathe, which consists of the bed and two supporting centers. Cells made of paraffined paper are placed in the slots to protect the coils while winding. Fig. 5 shows the method of placing the coils on the core. The short side of the coil is placed in the bottom of a slot which may be designated No. 1; then, looking at the commutator end of the core and counting in a counter-clockwise direction, the long side of the coil is placed in the top of slot No. 12. The second coil is similarly placed in slots No. 47 and No. 11, the third coil in slots No. 46 and No. 10, and so on.

The upper sides of the first eleven coils placed are not forced into the slots, as they have to be raised in order to place the short side of the last eleven coils. Both sides of the twelfth and remaining coils, however, will be in place permanently, and may be driven into the slots. To wind the last eleven coils, the upper side of the first eleven are lifted out of the slots and forced back, so as to give sufficient room to place the last coil. Fig. 6 shows the core partly wound. When all the coils have been placed on the core, the raised parts are then forced into their permanent position. A fiber drift and a rawhide mallet are used to force the coils into place, thus avoiding injury to the coils. To make the armature symmetrical, the coils are trued up, so that the projecting parts are equally divided between the two ends of the core. A temporary band of copper wire is put on at each end of the core to hold the coils in position.

The first insulation test is now made, and consists in applying a potential of 3 600 volts between the coils and core. To do this the insulation is removed for about one inch from the upper row of leads, which are then connected together by a bare copper wire; one of the potential leads is connected to this wire, which insures a good contact to all the coils, while the other terminal is placed on the core, and any ground will be indicated by the opening of a circuit-breaker, which is connected in the line circuit of the testing transformer. If the insulation proves satisfactory the commutator-end of the coils is insulated preparatory to connecting the leads to the commutator. This consists in covering the bend of the coils with two duck blankets. These are given a neat fit, and are then kept in position by a cord tied in six places around the armature. The cord is passed down between the coils at the end of the core, brought up over the blankets and firmly tied. Be-

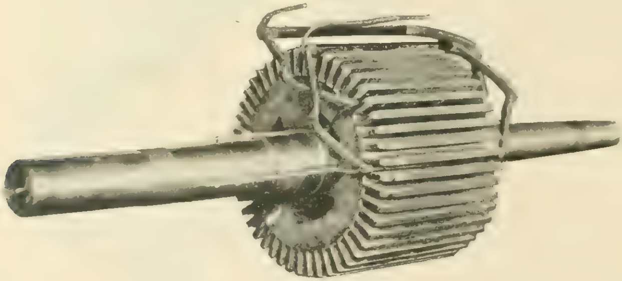


FIG. 5—ARMATURE CORE

fore the commutator is put on the shaft, the lower leads must be bent into position for connecting, because the commutator fits up closely to the coils, just leaving sufficient room for the leads. The lower layer, cosisting of the leads from the under side of the coils, goes to the right, the operator facing the commutator. Fig. 7 illustrates the method of bending the leads. They are carried to the right, giving them approximately the right pitch, and then back on the core, being held in position by the upper layer of leads until they are connected to the commutator.

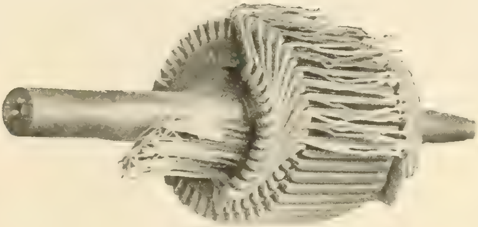


FIG. 6—PARTIALLY WOUND CORE

Connecting—The commutator is now forced on the shaft by a press. Besides the tightness of the fit, the commutator is prevented from moving on the shaft by a key. This key also serves to line up the commutator with the core, because the key-way on the commutator bushing is laid off so as to give the required position of the segments with regard to the core. This fixed relation between the armature winding and the commutator bars is necessary on account of the fixed brushes used in railway motors. That is, a conductor must be connected to such a bar, that when the

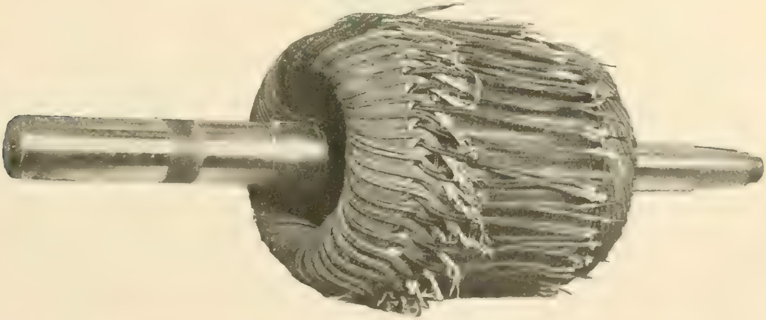


FIG. 7—ARMATURE WITH LOWER LEADS BENT IN PROPER POSITION

bar is under the brush, short-circuiting the conductor to which it is connected, the conductor will lie between two adjacent poles.

Before connecting the coils to the commutator it is necessary to lay off the throw of the leads on the commutator.

The commutator pitch, expressed in commutator bars, is equal to the average pitch of the coil, expressed in conductors. Thus the commutator pitch is 47 and the two leads of the same coil are connected to commutator bars 1 and 48. A rule for obtaining the commutator throw (1+the pitch) which is applicable only to four-pole progressive windings is:

$$\text{Commutator throw} = \frac{\text{No. com. bars} + 3}{2}$$

This is derived directly from the formula for average pitch previously given.

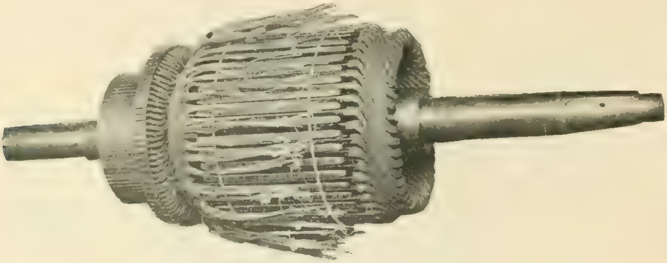


FIG. 8—ARMATURE WITH LOWER LEADS CONNECTED TO COMMUTATOR

The throw of the leads is now laid off on the commutator; the center of any coil is taken, and a point opposite to it is marked on the commutator and, in 12 A armature, this point will lie on the mica insulation between two bars. If the throw is over an equal number of bars, then half the number is taken in each direction around the commutator from the center point. But if it is an odd number of bars, the odd bar is added to the pitch of the upper row of leads.

Having laid off the throw on the commutator, the lower row of leads are connected first. Take the lower lead of the coil for which the commutator throw has been laid off and connect it to the proper bar. The insulation is skinned off that part of the lead which will lie in the commutator neck, and the lead is then forced to the bottom of the slot.

The remaining leads are brought forward in regular order and connected to the proper bars. Fig. 8 shows the armature with the lower row of leads connected. When all the lower leads are connected, a test is made in order to be sure that there are no wrong connections. The method of testing the connections, or "lighting-out," as it is called, is to use a lamp circuit, one wire of which has been cut and terminals soldered on the ends. When one terminal is placed on the commutator segment and the other on the upper lead of the same coil, then the lamp circuit is closed through the coil and the lamp glows. The terminals are moved consecutively around the commutator segments and the leads of the upper row and, so long as the lamp glows for each position, the connection has been properly made. Having tested out the lower row and finding the connections to be correct, the leads are insulated. This consists in covering them with three layers of friction cloth, which is bound with tape. The friction cloth makes a smooth surface for the upper row of leads to lie on, and these are now connected, giving the first lead the proper pitch forward as previously laid off on the commutator. When the leads of one coil are in position it is a simple matter to place all other leads symmetrically. Fig. 9 shows a view of the armature with all the leads connected and before they have been soldered. Before soldering, however, the second insulation test is made, and consists in applying a potential of 3,300 volts between the coils and core. The terminals of the testing transformer are placed on the commutator and core respectively. If the insulation stands the test the leads are then soldered to the commutator. When soldered, the armature is again placed in a lathe and the commutator is turned down 1/32 of an inch. This is to remove all particles of solder which may be sticking to the surface and short-circuiting the bars.

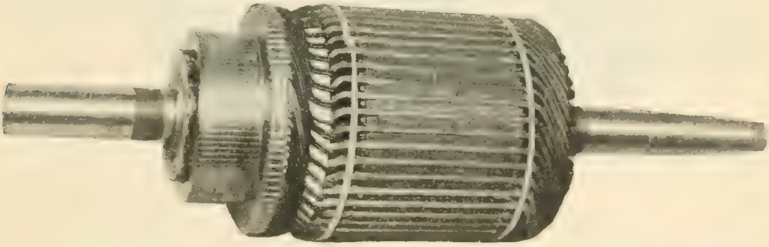


FIG. 9—ARMATURE WITH ALL LEADS CONNECTED TO COMMUTATOR

The commutator is polished with sandpaper and gives a smooth, even surface for the brushes to bear on.

Banding—The last step in the construction is to band the armature. Seven strips are placed on it—four on the core, one on each end of the coils and one to hold the leads in place. The bands on the coils should be wound out as far as possible without danger of their slipping off the ends, while the others are made $\frac{5}{8}$ inch wide. The coils are first pressed down into the slots by a copper strap tightened by a screw, and then the insulation under the bands is put on. The bands on the core are insulated by one layer of mica and fullerboard, while the coils are protected by one layer of bond-paper with two layers of elastic tape. The insulation is made of sufficient width to leave $\frac{1}{8}$ inch on each side of the bands. The wire used is .045 medium hard steel, tinned, and has a tensile strength of 204 pounds. The armature is rotated in a lathe and the wire is wound under a tension of about 100 pounds. The separate turns are soldered together and are further held by clips soldered across the band.

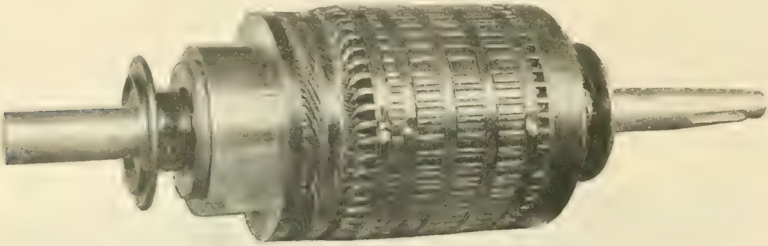
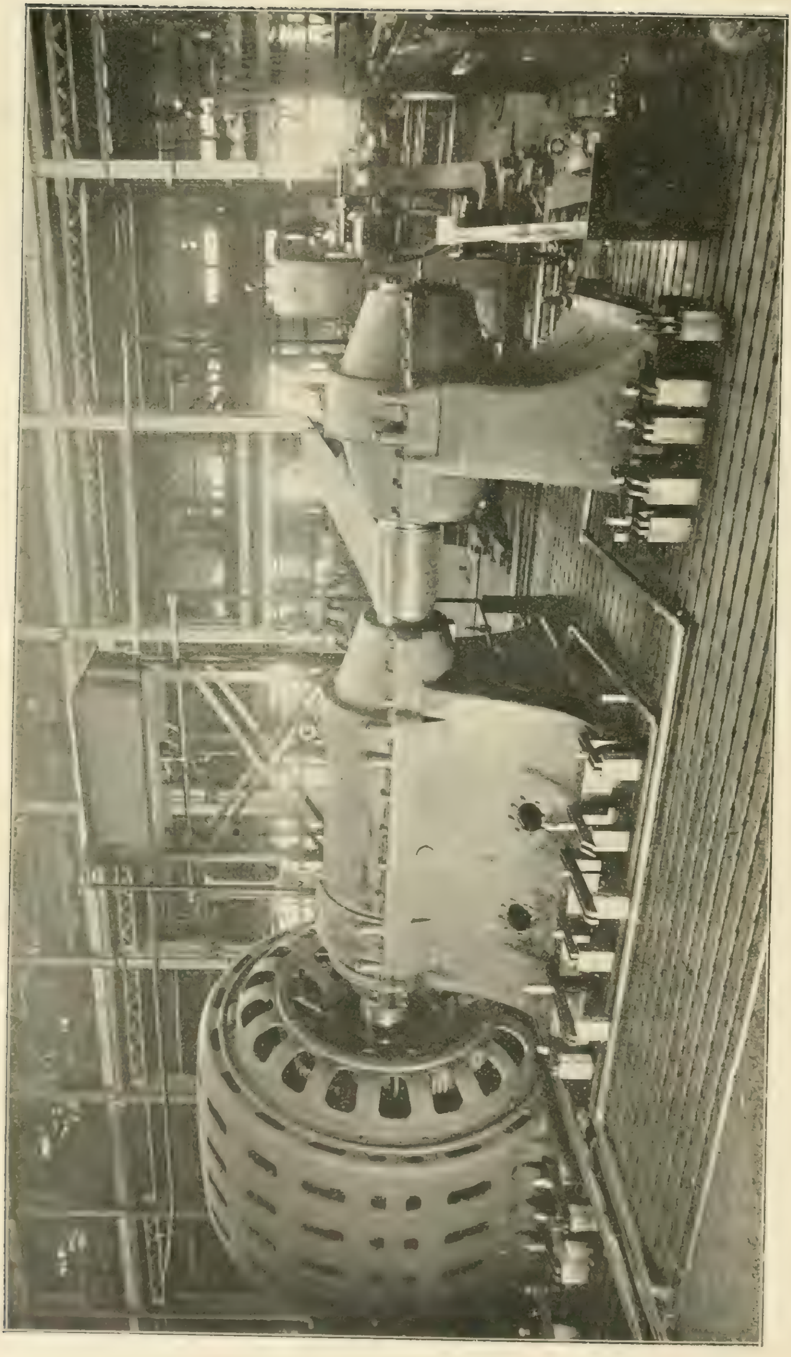


FIG. 10—FINISHED ARMATURE

The third insulation test is now made and a potential of 3 000 volts is applied between the coils and core. The armature is also tested for short circuits by the method described in the March issue of the JOURNAL. Fig. 10 shows the finished armature after it has been given a coat of insulating paint, and after the oil wiper-rings have been pressed on the shaft. It is now ready to be assembled with the remaining parts of the motor.



5 500 KW TURBO-GENERATOR ASSEMBLED FOR TEST

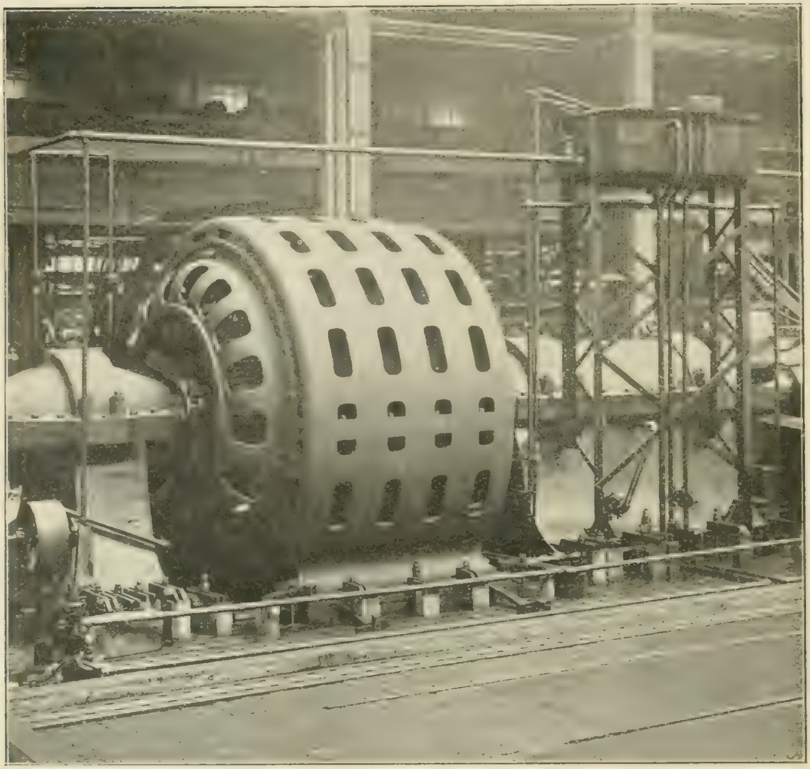
THE TEST OF A 5500 KW TURBO-GENERATOR

By FRED P. WOODBURY

RECENTLY the largest turbo-generator ever built was put on test in the testing department of the Electric Company. The frontispiece and the accompanying photographs show the appearance of the machine as it was assembled for testing. This generator is the first of eight to be built for the Metropolitan and District Electric Traction Company of London. It is 5 500 kw capacity, 3 phase, 11 000 volts, 33 cycles, and runs at a speed of 1 000 r.p.m. The high peripheral speed at which the revolving field is designed to run necessitated special construction in both the revolving part and in the bearings, and the purpose of the tests made was to determine the effectiveness of the novel construction, rather than to determine the electrical performance. In fact, the armature core was assembled in temporary form and without the armature winding, so that the electrical readings taken were of comparative value only.

The regular bearings for the turbine and generator form part of the turbine-end of the unit which necessitated a set of testing bearings beind made. These bearings are very well shown in the photographs. The middle pedestal contains two bearings, a coupling betweeen the generator shaft and pulley shaft occupying the space betwen them. The bearings were supplied with a continuous flow of oil by means of the oil reservoir and pipes shown. After passing through the bearings the oil was pumped through cooling coils and then to the reservoir when it was ready to pass through the bearings again. During the tests the generator was driven by a 400 kw, 500 volt direct-current motor by belt.

The tests were almost entirely no-load runs at full speed to observe the mechanical action of the revolving part under these conditions. Some electrical readings were taken of the iron-loss and friction and windage-loss. For the iron-loss readings, for which it was necessary to observe the induced armature voltage a temporary winding, consisting of one rubber-covered cable per slot in two-thirds of the slots, were used. On account of the enormous



5 500 KW TURBO-GENERATOR SHOWING OIL RESERVOIR AND PIPES

inertia of the plant it was very difficult to get readings of the motor input that represented the actual energy in the plant. When the line voltage fell the motor could not decrease its speed due to the inertia of the revolving field, and the momentum supplied energy to the motor; and when the line voltage rose the inertia prevented the speed from increasing, imposing an additional load on the motor. The electrical readings only represented the power required to run the plant when the line voltage was held practically constant. This was accomplished by putting a booster in the supply circuit. One of the minor objects of the test was to observe the noise made by the generator. Only a low hum, not at all unpleasant, was made by the revolving part. No difficulties were encountered in these tests of a 5 500 kw unit that would indicate a limit in the development of this type.

TRANSFORMER OIL

By C. E. SKINNER

THE use of oil as an insulating medium dates back to the early days of electrical work. The first suggestion of the commercial application of petroleum oil as an insulating medium seems to be due to Prof. Hughes, who proposed to employ it in connection with the insulation of submarine cables in 1858. In the early cable work the oil was used to saturate the fibrous materials separating the copper from the sheath, instead of forming the total insulation as suggested by Prof. Hughes. It was not, however, until the beginning of the last decade, when long-distance transmission of power began to assume shape and the use of oil for insulating purposes became general, that careful investigation of the subject became necessary.

Previous to 1890 there had been a limited use of oil for insulating transformers and induction coils, but this was confined to a few of the small sizes and low voltages in transformer work. In 1891 the Frankfort-Lauffen experiments were carried on and oil-insulated transformers were used, these transformers being wound for a line e.m.f. of 30 000 volts. It is interesting to note also that the line insulators themselves in this transmission were provided with oil cups, the object of the oil being to reduce the surface leakage over the insulator, particularly in damp weather. This type of insulator has been entirely abandoned at the present time.

When the first high-tension plant was designed by the Westinghouse Company in 1891 to be installed at Pomona, California, the writer was detailed to investigate the subject of the suitability of oil as an insulating medium for the transformers. A very few experiments sufficed to show that mineral oil would be suitable, and, on account of its cheapness, the investigation was confined almost entirely to mineral oils, and the oils tested were largely the oils in commercial use at that time for various purposes. Tests were made on grades varying from the heaviest cylinder oils to the lightest burning oils. The final selection was made on the basis of the insulation tests and on the flash and fire tests. Uniformity of insulation test was considered of more importance than an exceedingly high test. A flash test was selected which would be sufficiently high to prevent trouble due to the temperatures reached in normal operation. The oil selected is known to the trade as Diamond paraffine oil.

Since the installation of the above plant, much has been added to the general knowledge of the subject and much work has been done by the manufacturers of oil to produce a brand which will be best suited for the purpose. As before stated, mineral oil is used almost exclusively for this work, and in this paper mineral oil only will be considered.

At the present time the use of oil for the higher-voltage transformers is considered absolutely essential, and a very large proportion of the low-voltage transformers of large size are also oil-insulated. The use of oil for small house-to-house transformers is now almost the universal practice in this country. The total consumption of oil for insulating purposes runs into the hundreds of thousands of gallons per year, and it is therefore pertinent to discuss some of the qualities which go to make up a good oil and to outline some of the tests which may be made to determine whether or not any given oil has these qualities.

By transformer oil is meant an oil in which the transformer is completely immersed, forming a homogeneous insulation for those parts of the transformer which are not otherwise insulated, and also adding to the insulation of such materials as may be permeated by the oil, such as the cotton covering of the wire used. The transformer oil also forms a cooling medium whose function is to receive the heat from the coils and core, where it is generated, and carry it to the outer and cooler parts of the transformer. Owing to the fact that the oil expands when heated, the hot oil rises and the colder oil from the sides of the containing tank flows in to take its place, thus setting up a circulation of the oil which continually cools the transformer.

INSULATION

All oils—mineral, vegetable and animal—when pure, so far as the writer has been able to test them, are very good insulators. There is a wide difference in the insulating qualities of various mineral oils, but this difference seems to be more an index of the purity of the oil than an inherent difference due to variations in the chemical composition of the oil itself. By purity, is meant freedom from acid, alkali, water or foreign matter of any kind. The method usually employed in determining the insulating value of an oil is to test its dielectric strength. Satisfactory insulation resistance measurements are difficult to make, and while showing something of the quality of the oil, are not of as much value as dielectric tests. As the actual values of the dielectric strength obtained vary greatly with the testing conditions, it is best to use a standard method and always follow this out carefully. Satisfactory comparative values may then be obtained and the general insulating value determined with sufficient exactness for all practical purposes.

The usual method of testing consists in immersing a spark-gap in the oil, the gap being set at a known distance, and gradually raising the potential until rupture occurs. In making such tests the following points should be observed:

The spark-gap terminals should always be of the same shape and nicely polished, especially if the gap is quite small. Slight roughness or points on the testing terminals will change the apparent dielectric strength of the oil.

The gap should always be at the same depth in the oil. A variation in depth, consequently a variation of the pressure, will cause a variation in the tests. The apparent insulating strength increases with the pressure.

The testing voltage should always be applied in the same manner. It is preferable to fix the gap and apply an increasing voltage until breakdown occurs; or a constant voltage may be applied and the gap gradually shortened until the distance becomes such that rupture occurs. In the former method the voltage may be very gradually increased, as may be done by controlling the field of the generator, or it may be applied in steps, either with or without opening the circuit between steps; but for comparative purposes one method only should be used.

The time of application of the voltage should be as nearly as possible the same, especially the time consumed after the voltage reaches say 50 per cent. of the dielectric strength. A longer time will give lower results, especially if the oil contains impurities which may "line up" between the testing terminals.

It is a good plan to make more than one test on each sample of oil, as the test value frequently increases with the first few tests, especially if the oil is well shaken after each test, so as to thoroughly mix with the oil the carbon formed by the arc and not allow it to concentrate between the testing terminals. When so shaken it must be allowed to stand until free from air bubbles before another test is made. This increase in dielectric strength seems to be due to the drying effect or to the burning out of impurities in the oil. The best oils do not usually show much increase with repeated tests. When the oil becomes very black and dirty from repeated tests, the dielectric strength drops rapidly.

The amount of oil used for each test should be the same in every case, especially if more than one break is made in each sample. It is obvious that the carbon formed by the burning of the oil will be disseminated through the oil and that the results will depend in some measure on the amount per cubic inch of oil. It follows from the above that if more than one test is to be made on a given sample, the amount of energy expended by the arc formed, due to rupture of the oil, should be the same, as nearly as possible, for each break. It is best to limit this to a comparatively small amount by a fuse or circuit-breaker in the primary of the testing transformer, arranged to open the circuit on a comparatively small current.

The frequency and the e.m.f. wave-form of the testing circuit should be kept the same in the successive tests. It was pointed out some years ago that oil is not as good an insulator for low as for high frequencies. There is, however, little variation for commercial frequencies. It is well known that a pointed or saw-tooth e.m.f. wave will break down insulation of all kinds more readily than a flat, smooth wave of the same square-root-of-mean-square e.m.f. The use of a resistance for varying the testing voltage is, therefore, very objectionable.

All vessels and apparatus used must be kept perfectly clean. A single fibre in the oil may reduce the insulation strength greatly if it happens to "line up" between the terminals. A small amount of moisture, as will be shown later, is particularly objectionable on account of the very great reduction which it may make in the insulating value of the oil.

It is best to allow the oil to stand a short time after pouring into the testing vessel, as the bubbles of air which are carried with the oil in pouring in, or due to the oil being agitated, will lower the apparent dielectric strength.

Insulation Test Apparatus—As a convenient method of testing, the author has devised a testing cup, which is shown in the accompanying illustration, Fig. 1. This consists of a 200 c.c. graduated glass cylinder 1$\frac{3}{4}$ inches inside diameter, with a hole drilled through the bottom, through which the lower terminal is inserted. The testing terminals consist of $\frac{1}{2}$ inch diameter brass balls fastened to 3/16 inch rods. The upper rod passes through a clamp, which is connected to a micrometer screw actuated by a milled head. The

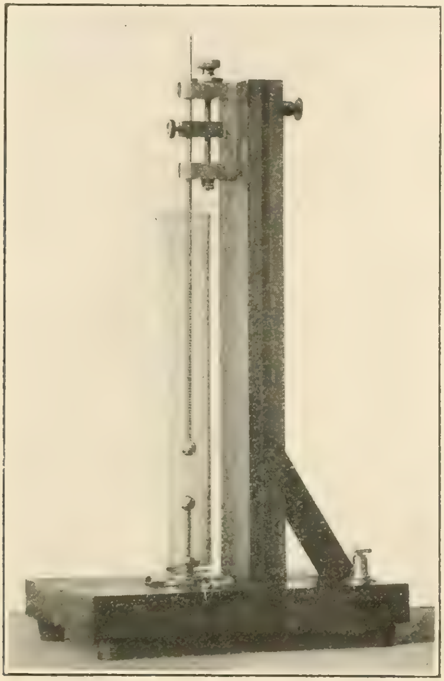


FIG. 1—OIL-TESTING CUP

lower terminal should fit in a socket so that it may be readily removed for cleaning. The bottom of the cup is made oil tight by the use of gaskets where the lower rod passes through the cup. An extension of the lower rod comes in contact with a spring set in the base of the stand to which the line terminal is connected by means of a convenient binding post. Stops are provided so that the oil vessel may always be placed in the same position. The upper rod may slide up and down easily when the clamping screw is free, or may be engaged with the micrometer screw at any point for adjusting the gap. All parts are therefore readily accessible for cleaning, and the zero point of the gap may be quickly adjusted for each test by allowing the upper rod to slide down, so that the terminals are in contact, and then clamping to the micrometer screw. The apparatus is always filled to the 200 c.c. mark (requiring a little less than 200 c.c. of oil for each test). The gap is adjusted to any convenient amount, usually 0.15 inches and the e.m.f. is raised gradually until breakdown occurs. After trying numerous forms of testing apparatus for this purpose, this method has been adopted as the most convenient, and it has the advantage of requiring a comparatively small amount of oil for each test.

FLASH AND FIRE TEST

By "flash test" is meant the temperature to which the oil must be heated in order to give off gases which burn when ignited and which form explosive mixtures with the surrounding air. By "fire test" is meant the temperature to which the oil must be heated so that the oil itself will take fire and continue burning when a flame is applied to its surface. The general method of determining the flash and fire test of an oil is to heat the oil gradually, applying a test flame at intervals and noting the temperature at which a slight flash occurs on the surface when the testing flame is applied, and the temperature at which the gases take fire and continue burning.

There are various types of apparatus on the market for making flash and fire tests. These may be divided in general into two classes—the open cup method and the closed cup method. For oils having a flashing point as high as ordinary transformer oil, the open cup method is preferable. The results reached by any method will depend largely on the taking of various precautions, which have been summarized by Gill in his "Handbook of Oil Analysis" as follows:

1. *The Rate of Heating*—The faster the oil is heated the lower will be the flash point, as more vapor is driven out.

2. *Size and Depth of Cup*—From a large and shallow cup the liquid evaporates faster; hence the lower will be the flash point. The most constant results are obtained from a deep cup about half filled.

3. *Quantity of Oil*—The larger the amount of oil the more vapor will be driven out; hence the lower will be the flash point.

4. *Distance of Testing Flame*—The nearer, or—what amounts to the same thing—the larger the testing flame the lower will be the flash point. A large flame may produce local super-heating.

5. *Point of Application of Testing Flame*—The flame should be applied at the edge, as the mixture of air and vapor is more complete; this is best effected by drawing the flame diametrically across the top of the cup. Dr. Dudley cites an instance in which the flash point obtained was considerably too high, owing to the fact that the testing flame was first applied in the centre of the cup.

6. *The Thermometers* used should be frequently compared with a standard instrument.

7. *Draughts* should be carefully avoided.

Two general methods of heating the oil may be employed. In the first the oil is placed in a vessel which is immersed in a second vessel filled with a very heavy oil which transmits the heat to the oil to be tested. In the second method the heating flame is applied directly to the cup or to a sand bath on which the cup rests, the testing cup being protected from draughts. Both methods have their adherents, although the second one seems to be used more extensively for the high flash test oils. The author has found the New York State Board of Health Tester, used with cover removed, very satisfactory. This testor is of the first class, using a bath in which the testing cup proper is placed.

The following is quoted from a specification for transformer oil:

"*Flash and Fire Tests*—In making flash and fire tests the New York State Board of Health Tester will be used, *with cover removed.* The upper cup will be filled to within one-fourth of an inch of the flange joining the cup and vapor chamber. The rate of heating will be approximately 8° C. (14.4° F.) per minute, and the test flame, consisting of a gas jet approximately ¼ inch in length, will be passed slowly across a diameter of the cup ½ inch above the surface of the oil every 4° C. (7.2° F.), beginning at 150° C. (302° F.). The lower cup will be filled with a very heavy oil, and cold oil will be placed in the lower cup at the beginning of each test."

EVAPORATION

Mineral oils begin to evaporate slightly at a temperature somewhat below their flashing point and the evaporation is quite rapid at the flashing point and above. It is therefore essential that a transformer oil have a flash test sufficiently high so that evaporation will not take place at the ordinary running temperatures of the transformer. The evaporation test, if made at a temperature approximately 100° C., will also drive off any moisture which may be present in the oil. In the case of high flash test oils, the evaporation test at 100° C. may therefore show approximately the amount of moisture present in the oil. The evaporation test is not so necessary as the insulation and flash tests, but such test should be made occasionally on oil which is used for transformer work. A convenient method of making the test is to place a small amount of oil, usually approximately 2 grammes, in a small porcelain crucible and heat this over a water bath at a temperature of approximately 100° C. for 10 or 12 hours, then determine the percentage evaporation by loss in weight.

MOISTURE

The deteriorating effect of moisture on the insulating quality of an oil is very marked. As there are a great many ways in which the oil may take up moisture or moisture be introduced into the oil, tests for moisture become very important. A very easy and satisfactory method of making test for moisture has been suggested to the author by a prominent oil chemist. This test consists in placing a small amount of oil in a cup, into which is plunged a piece of iron or other metal which is heated to a temperature just below a dull red heat. Any hissing or crackling noise indicates the presence of moisture. Another method of testing for moisture is to place a small amount of anhydrous copper sulphate in a test tube and then fill the tube with the oil to be tested. After thoroughly shaking, a bluish tinge in the copper sulphate will indicate the presence of moisture in the oil.

It is difficult to determine the exact amount of moisture in oil when this amount is small, and this is usually not necessary as it is sufficient to know qualitatively whether or not moisture is present. In making test for the effect of different percentages of moisture in the oil it was found necessary to thoroughly dry the oil then introduce moisture in the form of water in minute quantities in a closed vessel and very thoroughly agitate the oil so as to disseminate the water through it. This method is not considered entirely reliable, but for testing purposes gave results so striking that a curve is given herewith, showing some of the results obtained. It is considered that the form of the curve is correct but it may be that the percentage amount of moisture present between the testing terminals is not entirely accurate. Check tests, however, gave very close results. It will be seen from this curve, Fig. 2, that moisture introduced into the oil to the amount of 0.06% reduced the dielectric strength of the oil to about 50% of the original value when it was known to be free from moisture, and that there was very little

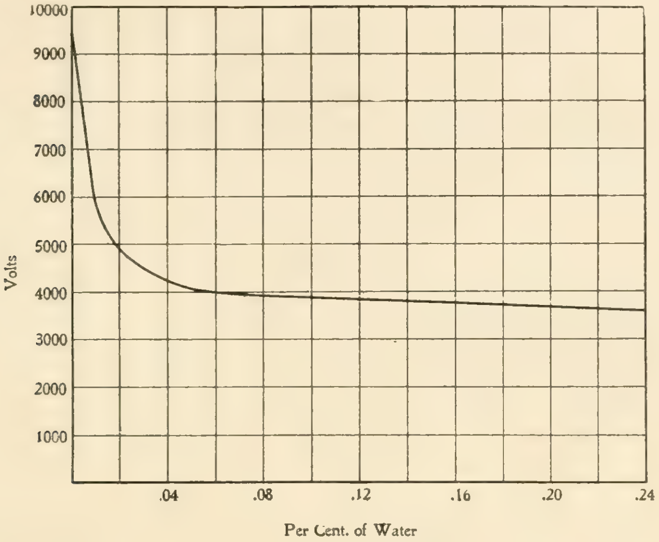


FIG. 2—CURVE SHOWING EFFECT OF WATER IN OIL

Terminals	½ in. balls
Gap	0.075 in.
Frequency	133 cycles
Wave Form	Sine

further decrease in the dielectric strength due to increasing the amount of moisture introduced in the form of water.

VISCOSITY

The viscosity of an oil has been defined as the degree of its fluidity, or its internal friction. The viscosity is not a function of the specific gravity, but in general the less the specific gravity the greater the fluidity of the oil. The viscosity of transformer oil, within limits, is not of very great importance, although in general the more fluid the oil the more rapid will be the circulation of the oil in the transformer tank and consequently the greater the cooling effect. The viscosity seems to bear no relation whatever to the insulation tests, the lighter oils—such as kerosene—showing as high, or higher insulation tests than the very heavy oils. Tests for viscosity require special apparatus and special care in testing, and such tests are not usually considered necessary in connection with transformer oil. Directions for making such tests may be found in any text on lubricating oils.

COLD TEST

The "cold test" of an oil is the temperature at which the oil will just flow. In ordinary transformer work this is of no importance whatever. It may be of importance to determine the cold test where the oil is to be used for oil-switch work, the switches being exposed to very severe cold. The cold test then becomes important, as the switch may not operate when the temperature is much below the cold test of the oil and the oil consequently in a solidified state. Cold test may be made by placing a test tube, partly filled with the oil, in a freezing mixture and noting the temperature at which the oil ceases to flow when the test tube is turned upon its side.

COLOR

For convenience in handling, it is desirable that a transformer oil be water-white in color, but this is not at all necessary, and as the production of a water-white oil usually means chemical treatment, it is best to use a darker oil rather than to risk any chance of having traces of chemicals in the oil. Most oils get darker with continued use. The quality of the oil from an insulation standpoint does not apparently suffer any change whatever due to darkening under the influence of temperature.

SULPHUR COMPOUNDS

The action of sulphur on the insulation of transformer oil, while not yet thoroughly investigated, has shown in the few tests which the author has carried out, to be very detrimental, and it is therefore considered best to eliminate sulphur compounds from the transformer oil. Western oil is particularly liable to contain sulphur compounds, and is therefore liable to give trouble from this cause. In some tests carried out some time ago the insulation resistance of a model transformer, after remaining at a very high value at high temperatures for nearly a year, was lowered to the danger point in a few days by the introduction of a small amount of sulphur into the oil.

DEPOSIT

In actual service it sometimes occurs that a brownish or black deposit is formed in the oil. Careful experiments have shown that this deposit is a phenomena of temperature alone. This deposit is formed from the oil and from the insulating materials in the way of varnishes, etc., which are used in the solid insulation of the transformer. The deposit itself is a good insulator, and the only harm done by such a deposit is to impede the cooling of the transformer by lodging in the ventilating spaces and on the cooling coils of a water-cooled transformer. In very high-tension transformers there is also a tendency for this deposit, when it does occur, to line up at points where the stress is greatest. Such deposit does not necessarily mean a deterioration in the insulation of the oil or of the transformer, and occasional cleaning of the parts on which the deposit occurs is all that is necessary to keep the transformer in good condition. Where the transformer tops are partly open the deposit will contain dust and dirt which naturally get into the transformer case.

SPECIFICATIONS

In the foregoing the writer has endeavored to give some of the qualities necessary in a transformer oil and to describe some of the tests which will show whether or not the oil fulfills these conditions. In the following will be found a brief specification for a transformer oil, giving more in detail the exact requirements which the oil should fulfill:

(1) The oil should be a pure mineral oil obtained by fractional distillation of petroleum unmixed with any other substances and without subsequent chemcal treatment.

(2) The flash test of the oil should not be less than 180° C. (356° F.) and the burning test should not be less than 200° C. (392° F.).

(3) The oil must not contain moisture, acid, alkali, or sulphur compounds.

(4) The oil should not show an evaporation of more than 0.2% when heated at 100° C. for eight hours.

(5) It is desirable that the oil be as fluid as possible and that the color be as light as can be obtained in an untreated oil.

The method of making tests to determine the above qualities should be distinctly specified so that there can be no misunderstanding on account of results being obtained by different mtehods of test.

The specification for flash test given above is intended to be low enough so that there will be some leeway to allow for slight variations in the oil and for variations obtained by different observers. It is expected that an oil to fulfill this specification will run something higher than 180° flash test.

In addition to the specification, the user should have the assurance that the oil is carefully made, that all containing vessels are clean and free from moisture, and that systematic tests are made on the finished material to see that it fulfills the conditions specified. He should also take the necessary precautions to see that no moisture is allowed to get into the oil after it is received by him. When oil is stored in barrels, the barrels should be kept under cover and water should not be allowed to stand on the heads, as it will often find its way through into the oil. Transformer and transformer tanks should be thoroughly dry before the oil is put in. In water-cooled transformers the cooling coils should be perfectly tight, and the end of the cooling coils where the water enters should be lagged so as to prevent condensation of moisture due to this part of the coil being colder than the surrounding air.

In the specification given above no insulation test is specified, for the reason that oil manufacturers at the present time are not equipped to make such tests, and the writer believes that as a fundamental principle specifications for materials should not impose requirements which both the producer and the user cannot check. It is suggested, however, that in making up specifications for transformer oil a clause be inserted stating that insulation tests will be made and that if these fall below normal the specification proper will be rigidly enforced.

It is to be hoped that manufacturers of all kinds of insulation will avail themselves of the apparatus which has been devised for making insulation tests, as the information gained is always of great value to the manufacturer and to the user of the material. This information frequently leads to an improved product, and certainly to a better understanding of the conditions under which such materials are to be used.

When a good oil has been obtained from the manufacturer and the necessary precautions have been taken to insure that it is kept clean and free from moisture, it forms one of the most satisfactory insulating mediums known.

THE EXHIBITION OF MICROSCOPIC VIEWS—Specimens of metal are usually prepared for microscopic examination as follows: The sample generally a cube one-half an inch on the side or a cylinder one-half inch in diameter and one-half inch long, is filed or turned smooth and one face is ground with moist emery on a wooden wheel. This face is then polished perfectly, first with infusorial earth and finally with rouge. The surface is then etched with iodine, ammonium nitrate or nitric acid. The color differs considerably with the substance used in etching and for specimens that are to be compared it is desirable to use the same etching agent. After careful washing and drying the sample is mounted under a microscope to which a camera is attached and a photograph of the microscopic appearance is taken. These photographs may be filed for reference and from them lantern slides may be prepared which may be used to exhibit the appearance to a large number of people at once.

Mr. Kendall, formerly of the Electrical Engineering office, and Mr. Lynch, Inspector of Materials of the Westinghouse Electric & Manufacturing Company, have devised a scheme for exhibiting the appearance directly from the specimen, thus avoiding the necessity for preparing slides.

The sample, prepared in the usual manner, is mounted on a convenient backing in the path of the beam from the lantern, but at a certain angle thereto. The beam is reflected from the polished and etched surface and, passing through the lenses, a magnified image of the appearance of the etched surface is focussed on the screen.

This method of exhibition was employed very successfully by Mr. Kendall in a lecture before the Materials Section of the Electric Club, January 14, 1904.

FACTORY TESTING OF ELECTRICAL MACHINERY—IV

By R. E. WORKMAN

REGULATION OF GENERATORS—The standardization Committee of the American Institute of Electrical Engineers defines regulation as follows:

Regulation in generators "intended for the generation of constant potential, constant current, constant speed, etc., is the maximum variation of potential, current, speed, etc., occurring within the range from full load to no load under such constant conditions of operation as give the required full-load values, the condition of full load being considered in all cases as the normal condition of operation," and deviation from this being measured as a percentage.

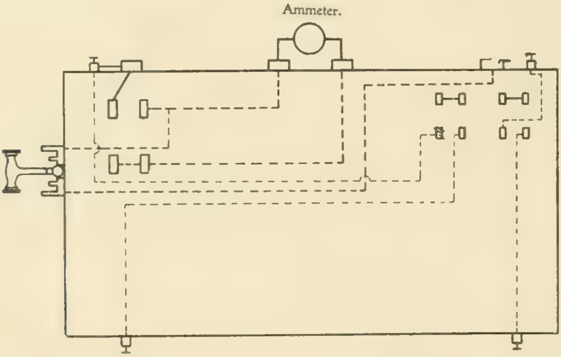


FIG. 18—RUNNING TEST TABLE USED FOR MACHINES UP TO ABOUT 100 KW

"The reguation of an apparatus intended for the generation of a potential, current, speed, etc., varying in a definite manner between full-load and no-load, is to be measured by the maximum variation of potential, current, speed, etc., from the satisfied conditions under such constant conditions of operation as give the required full-load values."

"Where the manner in which the variation in potential, current, speed, etc., between full-load and no-load is not specified, it should be assumed to be a simple linear relation; i. e., undergoing uniform variation between full-load and no-load."

"The regulation of an apparatus may, therefore, differ according to its qualifications for use. Thus, the regulation of a compound-wound generator specified as a constant potential generator will be different from that which it possesses as an over-compounded generator."

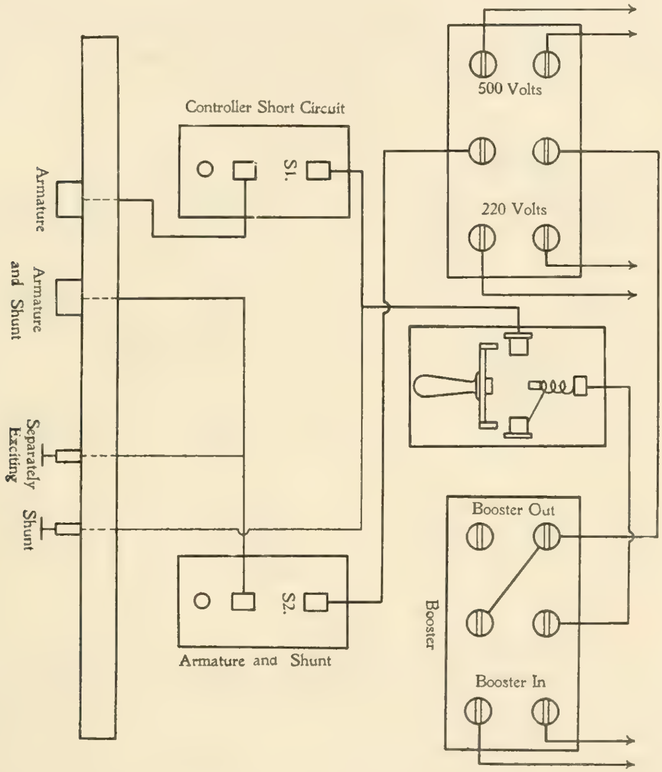


FIG. 19—POWER BOARD USED IN CONNECTION WITH TEST TABLE SHOWN IN FIG. 18

In the case of a shunt-wound generator the constant conditions under which the test is made are:

Constant speed.

Constant resistance in shunt circuit.

Constant temperature of 50° C in the various windings of the machine.

In the case of a compound machine, there is the additional condition, where there is a shunt to the series windings, that the resistance of this shunt be held the same throughout the test.

The drop in voltage in a shunt-wound generator with constant resistance in its shunt circuit is due to the resistance in the armature and the magnetizing effect of the armature upon the field, and also to the cumulative effect of a drop in voltage, in reducing the current in the shunt-field winding.

The drop in voltage due to the armature resistance is the product of the armature resistance from brush to brush and the total armature current. The effect of the magneto-motive force due to the currents in the armature windings is shown in Figs. 20 and 21.

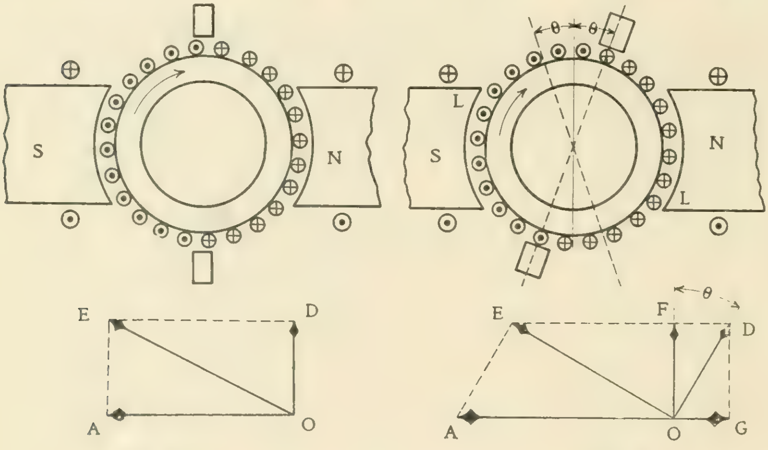


FIG. 20 FIG. 21

ARMATURE REACTION

Fig 20 represents diagrammatically a two-pole generator running with its brushes on no-load neutral with a very small current flowing. The bars in which the current is flowing from the reader are marked with a cross, and those in which the current is flowing toward the reader are marked with a dot. The current is supposed to be so small that the magnetizing force of the turns on the armature is negligible in comparison with that of the field turns. Now let the generator current be raised so that the magnetizing force of the armature turns is comparable with that of the field. It will be observed that this magnetizing force is directed in a line at right angles to that of the field magnetizing force. In the vector diagram at the foot of Fig 20, *O A* represents the field magnetizing force and *O D* that of the armature. The resultant, *O E* will be found by completing the parallelogram. It will be seen that the direction of this resultant will not be in line with that of the axis of the field, and therefore that the neutral position for the brushes will no longer be that shown in Fig. 20, but will be more nearly that shown in Fig. 21. It will be seen by reference to the vector diagram at the foot of Fig. 21 that the armature magnetizing force is no longer at right angles to that of the field, but is in the direction of a line joining the brushes, *OD*, in Fig. 21. *OE*, found by completing the parallelogram, represents the resultant magnetizing force. The armature magnetizing force may be divided into two components, one *O G* in the line of the magnetizing force of the field, but opposed to it in direction, and one *O F* at right angles to it, as shown in Fig. 21. The former quantity, *O G*, is called the back magnetizing force of the armature because it opposes the magnetizing force of the field. It is due to the current in the bars included by twice the angle of lead of the brushes, and thus does not exist until the brushes are moved forward. The latter quantity, *O F*, is called the cross magnetizing force of the armature, because its effect is at right angles to that of the field. It is evidently diminished by moving the brushes forward. The effect of the back magnetizing force is to weaken the field and thus decrease the voltage.

There are two methods of compensating for this drop in voltage:

(a) by hand regulation of a shunt-wound generator with the aid of a variable resistance in its field.

(b) by compounding turns on the magnets in series with the armature which add to the magnetizing force as the load increases.

In the case of a compound-wound machine compounding may be either for constant potential or for a rise in potential with an increase in load. Over-compounding is used to compensate for drop in potential in long lines and for drop in speed of the steam engine, or other prime mover, which drives the generator.

The regulation tests usually made are such as to determine, not only the regulation of the machine from full-load to no-load, but a curve showing the regulation of the machine from any desired load to no-load. In the case of shunt-wound generators a regulation curve is taken in which the shunt-field current is increased with the load so as to hold the voltage constant. This is really a "field-current regulation" with constant terminal voltage and speed, but is conveniently called a constant potential regulation, although it does not comply with the definition of a regulation given by the Committee on Standardization.

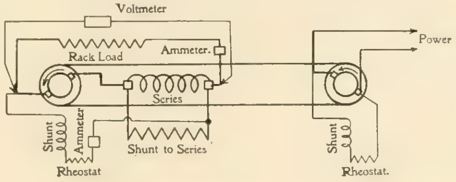
From the foregoing it will be seen that a regulation test has to be made with load on the generator, running under working conditions. There are two methods of loading machines, depending principally upon their size.

(a) *On Resistance Load,* such as coils of iron wire, banks of lamps, or water rheostats. In this method the power required to drive the machine will necessarily be greater than its full load output, and it is thus a very expensive matter to test a large machine in this way. In consequence of this the second method of loading has been devised.

(b) *Loading Back Method*—In this case two similar generators driven by a small motor and connected in parallel, are so adjusted that the machine to be tested generates a slightly greater e.m.f. than the other, and a current circulating through both armatures in succession is the result. It is evident that the machine generating the lower e.m.f. and consequently having current forced through it will act as a motor and produce a torque in the direction of rotation, which, when the current is large, will attain a high value. At the same time the machine generating the high e.m.f. will be running as a generator, and the current will produce a torque tending to stop it; this torque will have to be overcome by the joint action of the machine generating the lower e.m.f. and the driving motor. A little thought will make it evident to the reader that the power supplied by the driving motor is simply that required to overcome the loss in both machines. In this manner very large machines may be economically tested under conditions very closely approximating those of actual service. It is often necessary to combine the two methods where two machines of the proper dimensions cannot be obtained or where it is desired to test a generator and a motor of different sizes at the same time; this, of course, sacrifices a part of the advantage gained by loading back methods.

(a) REGULATION TEST WITH RESISTANCE LOADS

Preparations for Test—The table used is that shown in Fig. 22, and it is connected to the machines as indicated. A motor having a larger capacity than the generator to be tested is mechanically connected to it by means of a belt or coupling, the arrangement being such that the generator shall be driven at its proper speed. This motor, generally a 500 volt one, except in the case of very small machines, is connected through a pit and starting panel to the power. The speed of the set is regulated by means of a rheostat in the shunt field of the motor. There is also a rheostat in the generator shunt field to regulate its voltage. The load is varied by varying the amount of resistance in the rack.



Scheme of Connections.

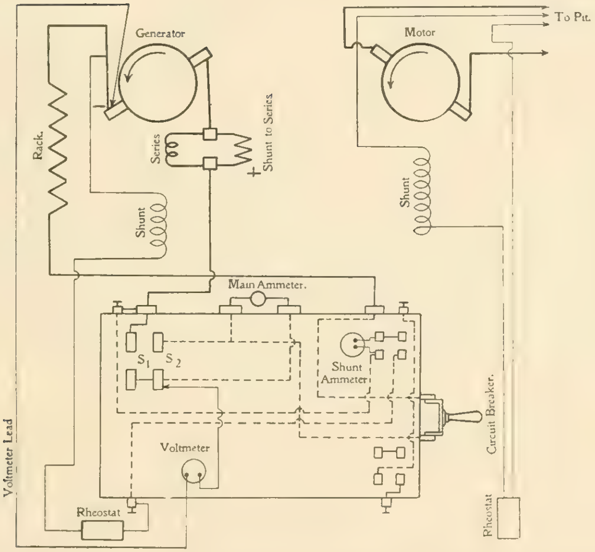


FIG. 22.—CONNECTIONS FOR REGULATION TEST WITH RESISTANCE LOAD

Before starting, the brushes of generator and motor must be set on trial full-load positions: in the case of the generator this will be in advance of the no-load neutral position; in the case of the motor it will be behind the no-load neutral position. The full-load position referred to is, of course, the position for best commutation at all loads between no-load and full-load.

Conduct of Test—The motor may now be started and brought to such a speed as to give the generator its designed speed. In the case of a compound generator a shunt is often put across the series winding to regulate the amount of compounding. In order that the compounding may be correctly set a greater number of turns than is actually necessary for the purpose has often to be put on. The effect of the shunt is, obviously, to divert a part of the current from the series coils and thus reduce their effect.

The readings are now taken in the following order:

(i) No-load reading to adjust the shunt field resistance for proper terminal voltage at no-load.

(ii) Full-load reading to adjust the shunt to the series winding, the form of resistance used on test for this shunt being usually a length of German silver strap.

(iii) Intermediate readings, all adjustments being left the same as in (ii).

The speed is held constant throughout. In every case the speed, terminal volts, external amperes, and shunt amperes are recorded.

Precautions to be Observed—The machine should be at a temperature of something like 50° C; if it is not, however, the difference in results may be allowed for by readjusting the length of the German silver shunt, if the machine has one, by means of readings taken after the temperature run. The resistance of the shunt sent out with the machine will be taken from this test. The resistance of the shunt used in the test is determined in the ordinary way or calculated from the dimensions of the strap used.

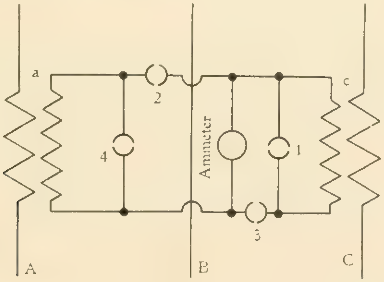
(To be continued.)

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

MEASURING CURRENTS IN THREE-PHASES WITH TWO SERIES TRANSFORMERS—The following method is often used in switchboard wiring where it is desired to measure the currents in a three-phase system by means of one ammeter and only two series transformers, instead of three which are usually necessary.

The diagram shows the lines *A, B* and *C* of the three-phase circuit, two series transformers, *A* and *C,* the ammeter, *AM,* and four switch-plugs, 1, 2, 3 and 4. To read the current in line *A,* the plugs are placed in 1 and 2; in line *B,* 2 and 3; in line *C,* 3 and 4; and when not using the ammeter the plugs are kept in 1 and 4.



By plugging in 1 and 2, *C* is short-circuited and the ammeter measures the current in line *A;* plugging in 3 and 4 short-circuits *A* and the current in line *C* is measured; by plugging in 2 and 3, the vectorial sum of the currents in lines *A* and *C* is measured by the ammeter, which is equal to the current in line *B.* This is true of any three-phase system, regardless of unbalanced loads or difference of power-factors in the phases.

When ammeter readings are not being taken, the switch-plugs should be in 1 and 4, short-circuiting the two series transformers; if the plugs are left out, the secondaries of the series transformers will be open-circuited in which case the primary current will saturate the core, overheating it and inducing a dangerous voltage in the secondary coils—*Switchboard Section.*

SIMPLE VARIABLE RESISTANCE DEVICE—A simple and convenient arrangement for obtaining a variable resistance to work in conjunction with banks of lamps or resistance racks to give finer regulation of current is that shown in the sketch. Five incandescent lamps are connected in series with the hinge jaws of the single-pole double-throw switches. A german-silver resistance coil, with sliding contact, is connected by plugs at *M* or *N*, so that it may be used in series with various combinations of the lamps. The end lamp has twice the resistance of any of the others. If the coil be designed to have a resistance equal to that of a lamp it will be readily seen that by proper arrangements of the switches and adjustments of the coil a great number of values of resistance may be obtained, which will range from a maximum, when the lamps are in multiple, to a minimum when the lamps are in series. Somewhat greater flexibility is obtained by using two coils instead of one and connecting them in series or parallel, as the occasion demands. This device is especially desirable for use in testing and calibrating instruments where very small currents are often used and where sma'l changes of current values are necessary.

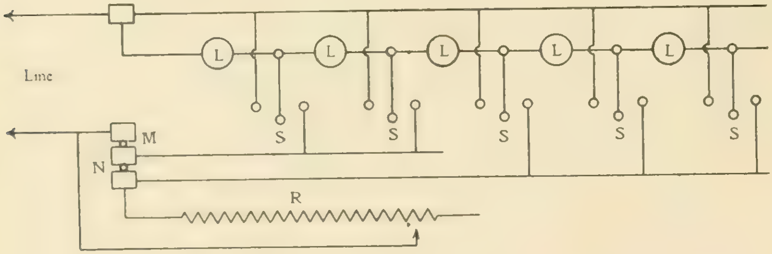


FIG. 2

HUBS OF LARGE ROTATING FIELDS—The cast hubs of the rotating fields of large generators are split to avoid the internal stresses due to unequal cooling after casting. The hub is bored to fit the shaft and after pressing on, a steel ring slightly smaller than the outer rim of the hub is heated till it will slip over the hub and allowed to cool and shrink tight. The slits in the hub are then filled with type metal, which expands in solidifying—*Materials Section.*

EDITORIAL COMMENT

"A Message to Garcia"

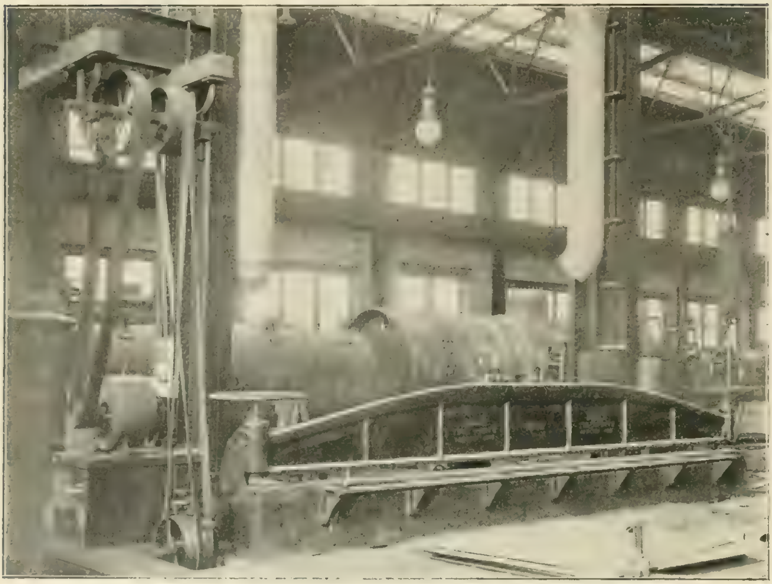
Some years ago a story called "A Message to Garcia" was given the widest circulation. No more fallacious or harmful attitude of mind could possibly have been advocated than that which was praised and lauded in the story referred to. The employer who does not recognize the necessity of questions being asked by his men and the value of the man with an inquiring mind is out of touch with his environment and is not fit to direct others. A successful organization would be impossible with men of the type of the hero of the "Message to Garcia."

The man who would be in touch with modern progress must learn the meaning of co-operation. Co-operation, first of all, predicates an attitude of mind free to absorb, free to give. No fear need be felt for the success of an organization in which this spirit is manifested by its individual members.

In any large group of individuals working to a common end there will be a great diversity of ideas and opinions and to accomplish the proper co-operation of these more or less independent forces is a problem of major importance. The retarding elements most difficult to overcome in effecting this co-operation are those resulting from the personal characteristics of the men concerned; the disposition on the part of men well-versed in their particular lines to give insufficient weight to the opinions of others in discussing problems of mutual interest; the tendency to exaggerate the importance of personal peculiarities, impatience under criticism, and the failure to submerge individual likes and dislikes.

It is probable that there is no element so destructive to co-operation in an organization as the dogmatic assertion, "It can't be done." The frequency with which this assertion is made comes from the conviction on the part of the individual that his peculiar relation to given problems renders his judgment infallible, overlooking the fact that fresh minds will often see truths which will not be apparent to minds grown stale in the consideration of the problem. The man who can learn to ignore a statement of this kind, and who can, with due regard to proper limitations, bring himself to an attitude of mind which considers "all things possible" will soon find himself doing more and being more in any organization of men, than the man whose characteristic remark is "it can't be done."

L. A. OSBORNE.



NILES PLATE PLANER BELT DRIVEN FROM A CONSTANT SPEED MOTOR

self. We then have individual motor drive, and the tendency has been to extend this arrangement even to many of the smaller tools. For a large percentage of the motor drive usually required, a constant motor speed only is necessary. This application is comparatively simple and needs no discussion.

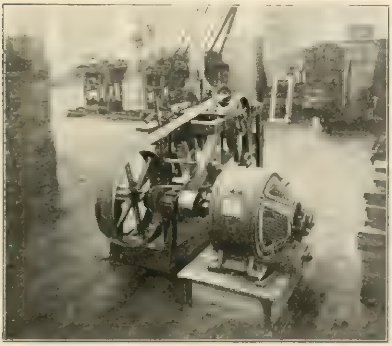
The methods in common use of joining motors to the driven parts are by belts, gears or direct connection. There are always, however, a large number of tools that require a variable speed. A constant speed motor driving these necessitates some form of a mechanical speed changing device, such as cone pulleys, gears, Reeves pulleys, and the like, for getting the different speeds. A vast amount of ingenuity and inventive skill has been employed in developing these mechanical devices and several are now on the market which are fairly satisfactory. One drawback to all, however, is the time required to make the speed changes. It is seldom possible to place these devices near the point where the work is being done, and in some of them the machines must be stopped to make a speed change. Experience has shown that these reasons prevent changes being made to the extent they should be made to get a maximum amount of work, and the result is a less output from the shop or factory.

VARIABLE-SPEED SYSTEMS

The desirability of getting a variation in speed from the motor itself and doing away with these mechanical devices obviously presents itself and has resulted in the development of a number of variable-speed motor systems. One advantage of getting the speed variations from the motor, instead of by mechanical devices, is that the machinist controls the speed without leaving his position, and this facility with which speed changes are made results in a largely increased output.

RAIL BORER DIRECT DRIVEN BY CONSTANT SPEED MOTOR

There are in general two classes of service requiring variable speed motors. In the first and probably largest class the output of the motor remains practically constant over the entire range of speed, i. e., the torque varies inversely with the speed. In the second class the output of the motor varies with the speed. In some cases it varies directly with the speed, i. e., the torque remains constant; in other cases the output increases faster than the speed.


STICKER DIRECT DRIVEN BY CONSTANT SPEED MOTOR

As the speed of a motor is almost directly proportional to the impressed e. m. f., it follows that a variation in speed can be obtained by varying the e. m. f. This method was the first adopted and it is still in use. Shunt field control obtained by varying the magnetic field strength by resistance in the shunt field windings is also largely employed. The number of voltages actually employed has been gradually decreased until at the present time the commercial systems in general use employ from 2 to 6, all combined with more or less shunt field control. There are also one or two systems using a single voltage.

Reference is made in what follows to "balanced" and "unbalanced" systems or circuits. A word as to the meaning of these terms may not here be out of place. A balanced system may be defined as one having similar electrical conditions on the separate circuits. In an unbalanced one the electrical conditions are not the same. Any unbalance in the systems referred to will be represented in amount by the current flowing in the neutral or intermediate wires.

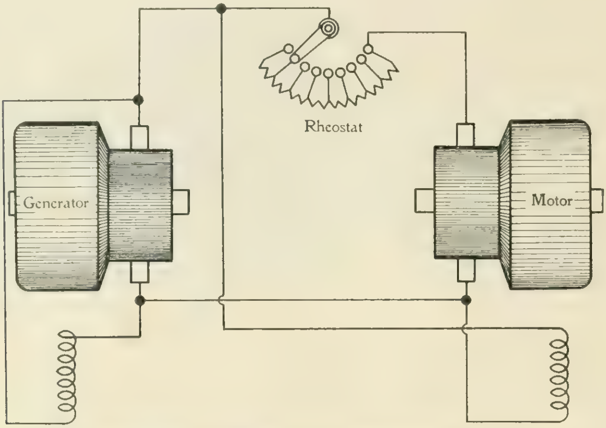
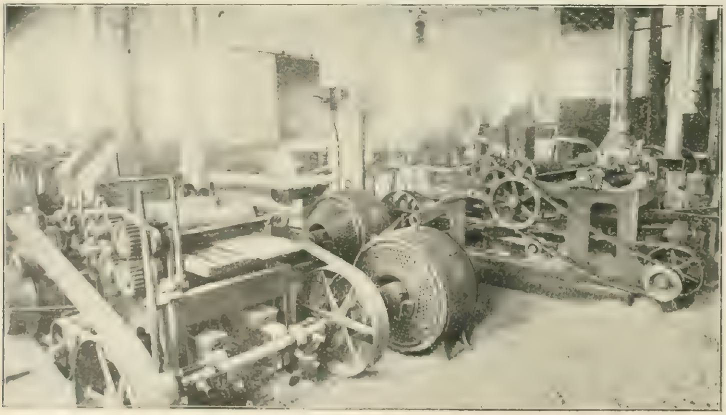


FIG. 1—VARIABLE VOLTAGE BY ARMATURE RESISTANCE

Variable Voltage by Armature Resistance—This is the earliest system and is still in use to-day for certain kinds of work. The voltage at the terminals of the motor is varied by connecting more



THE MACHINE TO THE LEFT IS A 14-INCH MOLDER AND THAT TO THE RIGHT IS A PANEL RAISER. EACH IS DRIVEN DIRECT BY A CONSTANT SPEED MOTOR

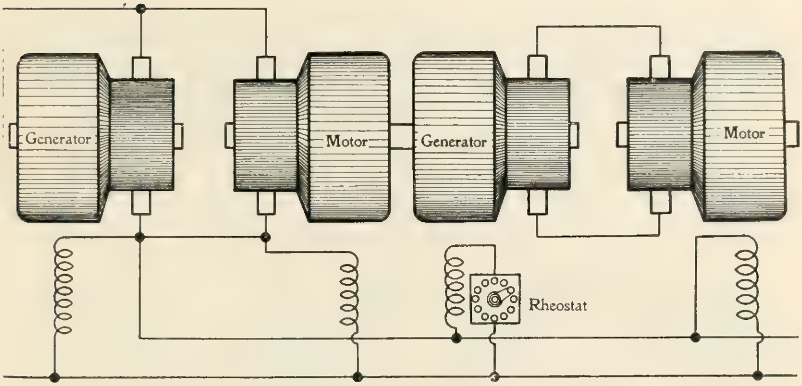


FIG. 2—VARIABLE VOLTAGE BY MOTOR GENERATOR SET

or less of an ohmic resistance in the armature circuit, as shown in Fig. 1. This method is in universal use on cranes and street cars, and has somewhat limited application with printing presses, fans, pumps and blowers. It is particularly well adapted for intermittent service with series motors; it permits the smallest possible motor to be used and it is therefore the cheapest. Its disadvantage where constant speed is required with varying load, is poor regulation. It is also a very inefficient method, as all the energy taken up by the series resistance is lost.

Variable Voltage from a Motor Generator Set—To avoid the losses incurred in using armature resistance, a system has been developed consisting in the use of a generator with each motor, this generator being so designed that its voltage may be varied over wide limits, thus supplying a variable voltage to the motor terminals,

NO. 5 NILES PLATE BENDING ROLLS, DRIVEN BY A 220 VOLT VARIABLE SPEED MOTOR

which are wired direct to the generator. It is shown in Fig. 2. Although this system is ideal in many ways and is capable of very wide application, its actual use is very limited. It is particularly suited to work where constant torque is required of the motor, where the same size of motor frame can be used as with the "armature resistance" method. In case, however, constant output over the entire range of speed is necessary, a larger frame is demanded with larger commutator and brush capacity. The motor must be large enough to give the required output at the minimum speed and the commutator of sufficient size for the largest current.

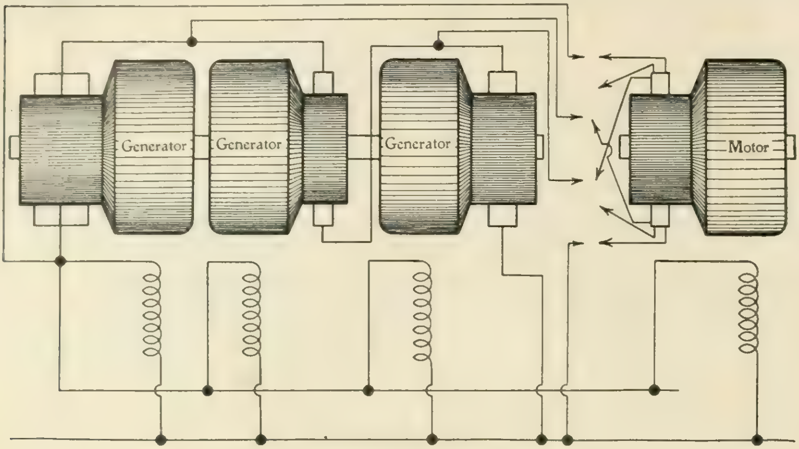
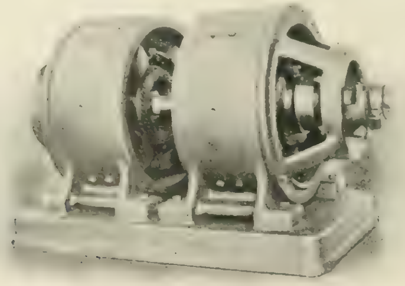
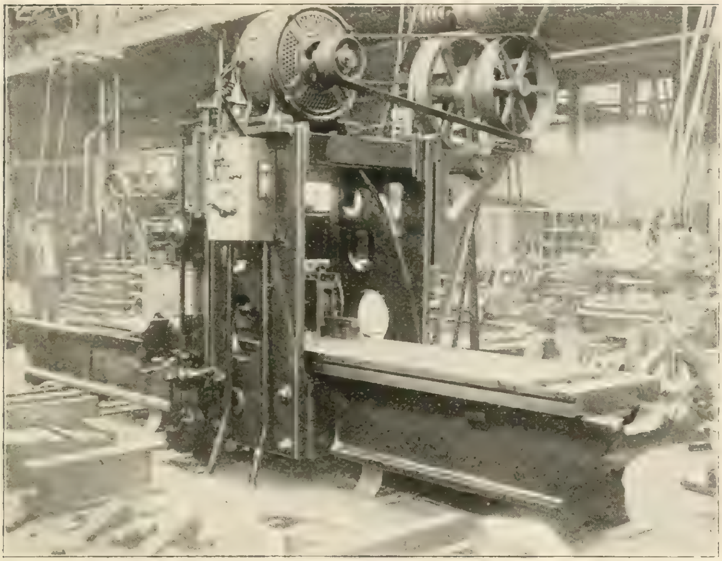


FIG. 3—THE MULTI-VOLTAGE SYSTEM

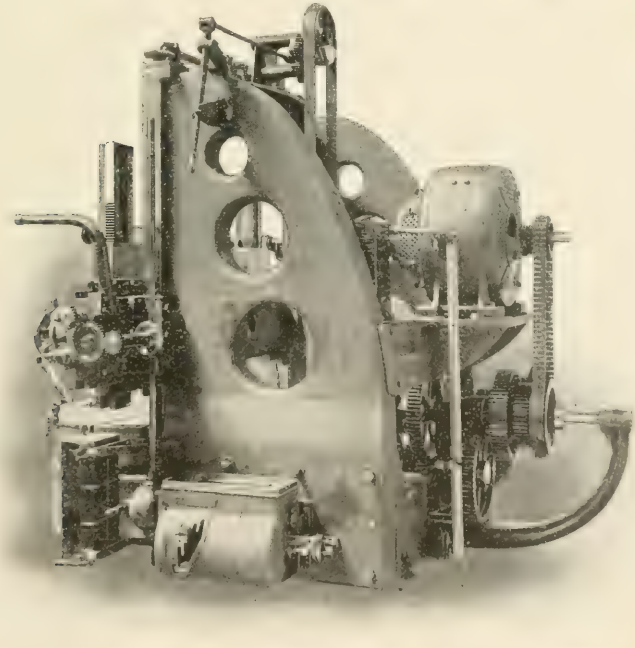
This system gives a wide speed range and perfect control with any desired number of speed notches. The main disadvantage of its use lies in the cost of installation, which is excessive, as three



BALANCER SET · THREE-WIRE SYSTEM



14-FOOT PLANER BUILT BY THE NILES TOOL WORKS, HAMILTON, OHIO.
DIRECT DRIVEN BY 10 H. P. COMPOUND WOUND MOTOR



61-INCH BULLARD BORING MILL, DIRECT DRIVEN BY A VARIABLE SPEED MOTOR
—THREE-WIRE SYSTEM

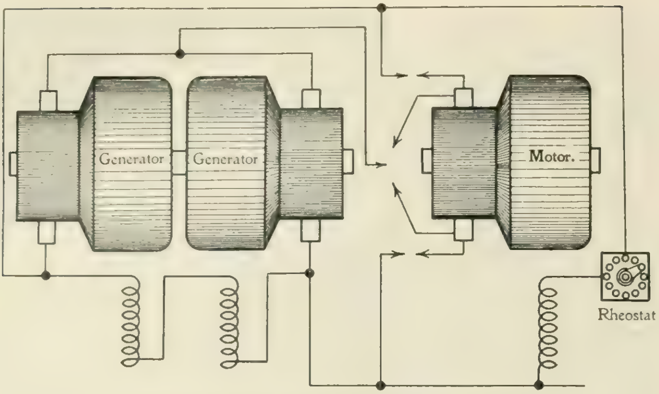


FIG. 4—UNBALANCED THREE-WIRE SYSTEM

machines are required for each motor application. To this fact almost entirely is due its very limited application.

Multivoltage System—The so-called multivoltage, or four-wire system, is an attempt at an approximation to the above system. It is capable of general application. Instead of a large number of different voltages obtained from a generator, it employs six, usually varying in arithmetical ratio from a minimum of 40 up to the usual line voltage of 240. (Fig. 3.) These voltages can be obtained from any two-wire system by means of what is commonly known as a motor-generator or balancer set. This consists ordinarily of three machines coupled together and connected in series across the line. Two extra wires are brought out between the machines which are wound for the different voltages desired. By combination of the voltages obtained from these machines, six are available for

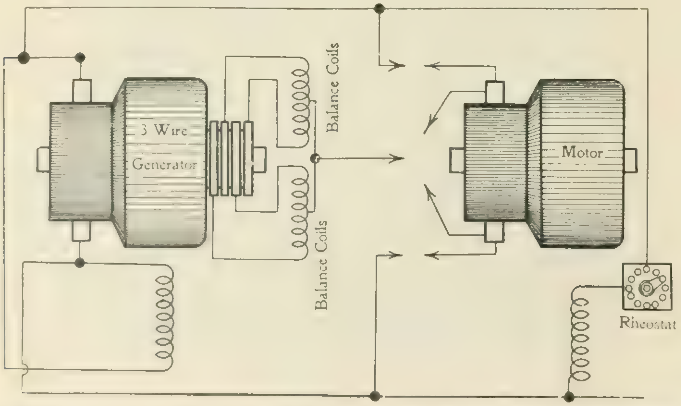
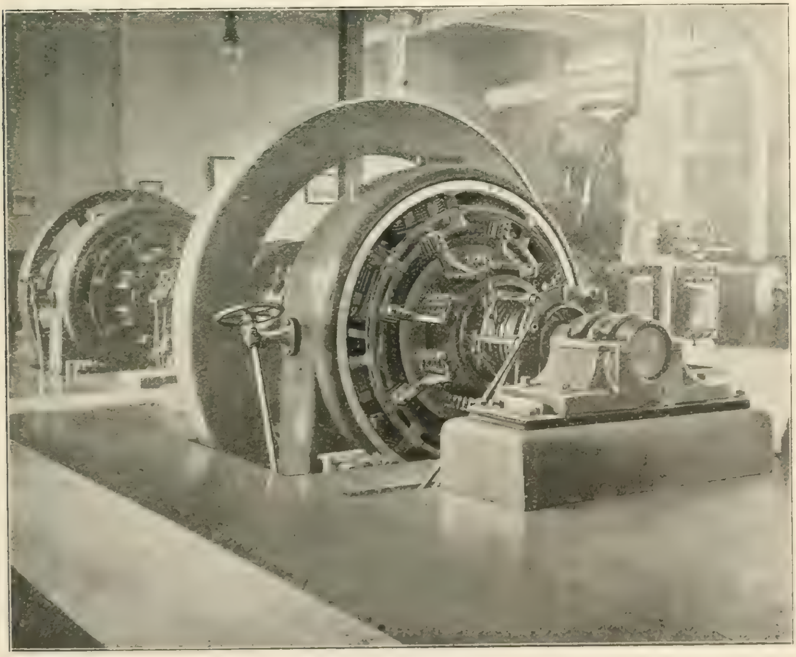


FIG. 5—BALANCED THREE-WIRE SYSTEM USING THREE-WIRE GENERATOR

use with the motor. It is much cheaper to install than the motor generator system, as a single balancer set can be made to do for any number of motors. Its undesirability lies in the cost of the balancer set, which is high owing to the special characteristics of the machine; and the cost of wire, which is high, owing to the fact that four wires must be put in throughout the entire installation. These wires must be of comparatively large size. All the auxiliary apparatus, such as meters, circuit-breakers, switches, fuses, etc., must be for four wires. The system is an unbalanced one, rendering good regulation difficult. Poor regulation is also obtained on the motors at the low voltages, owing to the heavy currents which must be used when constant output is required. This system involves in its latest developments the use of a small amount of shunt-field control sufficient to obtain speeds intermediate between those obtained on the line voltages.

Unbalanced Three-Wire System—The next step in the evolution of variable speed systems consists in the use of a three-wire unbalanced system from which three voltages are obtained. (Fig. 4.) It is much simpler than the multivoltage system, involves only



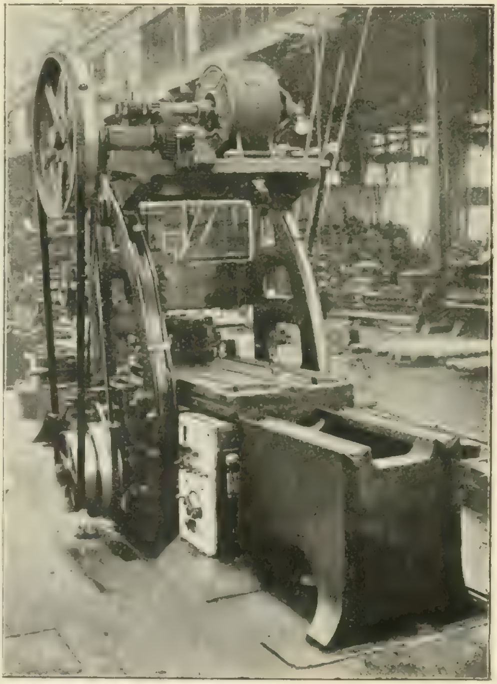
300 KW THREE-WIRE GENERATORS

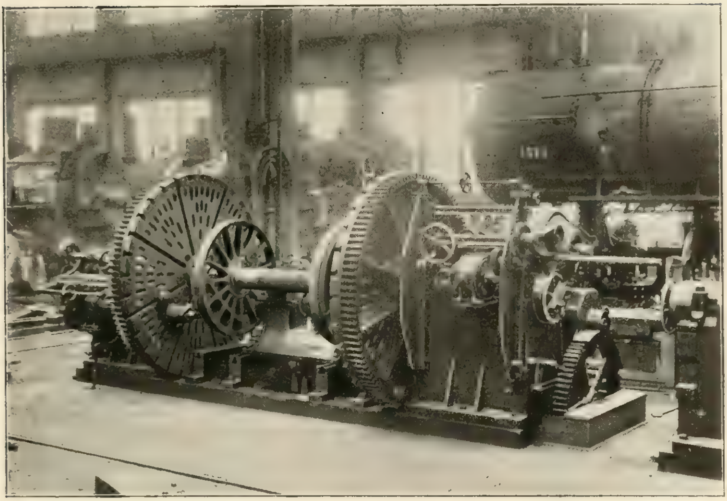
two machines for the balancer set, and the installation of but three wires with a correspondingly smaller amount of auxiliary apparatus. The middle wire must be comparatively large. Speeds intermediate between those obtained on the line voltage are secured by shunt-field control.

This system has so far had a very limited application. It gives slightly better regulation than the multivoltage system and is cheaper to install. On the other hand, one or both of the balancer machines must be special.

Balanced Three-Wire System—This is a three-wire system from which two voltages are obtained, one of which is one-half of the other. It is the ordinary three-wire Edison balanced system and is obtained either by two machines in series across the line or by the use of slip rings and auto-transformers from a standard two-wire direct-current generator or rotary converter. (Fig. 5.) A three-wire system can also be obtained from a two-wire system by a balancer set consisting of two machines connected in series across the line. Fig. 4 also shows this arrangement diagramatically.

The system consists of three wires, the middle, or neutral wire of which can be comparatively small, as the system is much more nearly balanced than any of the others which have been described. Two voltages are available for the motors, and the speeds, aside from those obtained direct from the line voltages, are secured by shunt-field control. This involves a wider speed range by field weakening than any of the systems previously mentioned. If the standard three-wire generator is used, the auxiliary apparatus to obtain the lower voltage is simple


10-FOOT PLANER DRIVEN BY 5 H. P. COMPOUND WOUND MOTOR



90-INCH WHEEL LATHE DRIVEN BY A VARIABLE SPEED MOTOR
THREE-WIRE BALANCED SYSTEM

and one that requires practically no attention. Where two generators or a balancer set are installed these consist of two standard generators connected in series across the line. When a balancer set is used, these machines can be smaller on this system than any other. Motors, when properly installed, will be connected so that one-half will be operated for their slow speeds on one of the side circuits and the other half on the other side circuit. The maximum unbalance which can possibly be obtained is one-half of the machines on one of the side circuits. The maximum unbalance that can be obtained with the other systems is all the machines on any one of the voltages. In case of breakdown of the balancing apparatus, one-half of the total range of speed is available from the higher voltage. On all other systems only the maximum speeds from the highest voltage can be used. In an emergency any two similar generators or motors of any voltage having sufficient current capacity can be used as balancers. The objection most generally raised to this system is the extent to which the field weakening must be carried to secure the necessary speed variation. All systems use shunt-field control. The amount of speed variation that may be obtained by shunt-field control is merely a question of design. The bad effects do not come from the field weakening, but from the reaction of the armature upon the weakened field. If this armature reaction be prevented by suitable design, no trouble will be caused by the weakened field. The best answer to this objection is that motors operated with the amount of field weakening required by this system give satisfactory performance.

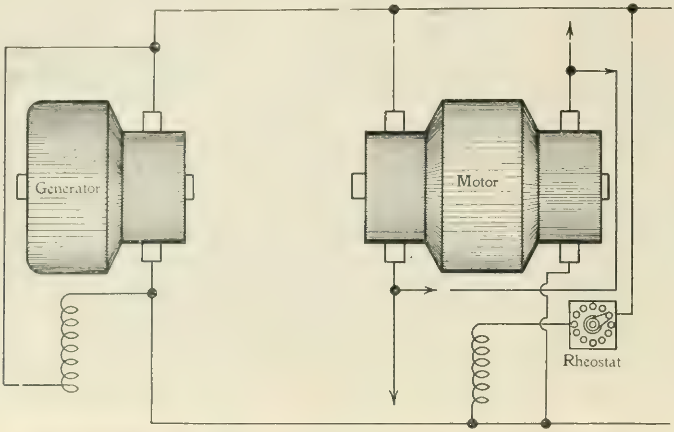


FIG. 6—VARIABLE SPEED OBTAINED FROM SINGLE VOLTAGE AND DOUBLE COMMUTATOR MOTOR

Double-Commutator Motors—There are some cases where only one or two motors are to be installed, a two-wire system is available, and the expense of putting in a balance set is such as to make a three-wire system objectionable. In such cases as this it is possible to use a double-commutator motor and obtain an exact equivalent of the results obtained with the three-wire systems. The armatures of these machines are provided with two independent windings and may be built in either one of two ways: first, by using two windings with a different number of turns in them, which is

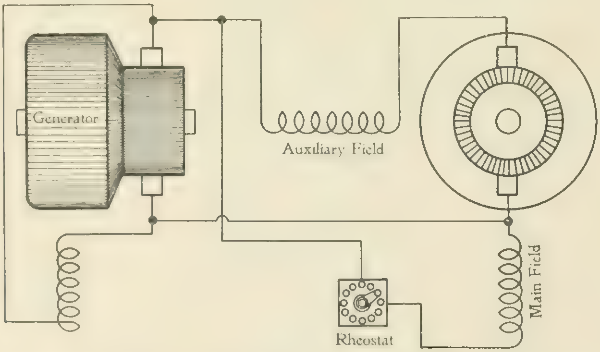


FIG. 7—VARIABLE SPEED OBTAINED FROM SINGLE VOLTAGE AND SHUNT FIELD CONTROL

an exact equivalent to the three-wire, three-voltage system; second, by making the windings on the two ends of the motor the same and connecting them first in series for the slow speeds and then in multiple for the high speeds, in this way securing an exact equivalent of the three-wire, two-voltage system. Shunt-field control is used in either case, the same as with the three-wire systems. The motor is longer than the single commutator machine and cannot be placed so near to the work to be driven.

Single Voltage With Shunt-Field Control—Standard motors of proper design will give a speed range of 2 to 1, or even 3 to 1 in some cases on a single voltage with shunt-field control. For speed ranges exceeding 2 to 1 there has recently been developed a system for single voltage work which is beginning to attract attention. Its application so far, however, has been small. It uses shunt-field control and a so-called compensating winding in the fields as shown in Fig. 7. This method consists of threading through the poles a winding which is connected in series with the armature and so proportioned that the strength and direction of the field set up by this winding is opposite to that set up by the armature. The effect of this winding is to neutralize the armature reaction. By the use of this system the field strength of the motor can be varied over a wide limit without seriously affecting commutation.

In considering the different systems of variable speed motor-drive, attention is at once directed to the evolution that has taken place. Starting with complicated and expensive systems, there have been evolved arrangements comparatively simple. The number of voltages has diminished so that the bulk of variable speed work is now done with one or two voltages, while the auxiliary apparatus and the cost of installation are much less than formerly; and these results have been accomplished without the use of excessively large motors. In all of the above systems the size of the motor is practically the same on the same basis of rating and speeds. The output and minimum speed fix the size of the motor frame irrespective of the system.

REAL ECONOMY IN TRANSFORMER OPERATION

By C. FORTESCUE

A GREAT deal of stress has been laid on the importance to station managers of a high all-day efficiency in the transformers used for lighting purposes, and the problem of designing such a transformer has usually been considered as involving:

(1) The interest and depreciation for a given time on capital invested in the apparatus, and

(2) The cost of energy dissipated by the apparatus during the same period.

It has been usual to consider the loss of profit incident to transformer losses as being equal to the product of energy lost through this cause during the given period and its cost per unit in coal.

In designing a transformer according to this method the iron loss is diminished until the increase in interest and depreciation on the cost of the transformer for a given time is balanced by the decreased loss to the lighting station through energy dissipated during the same period. In commercial designing it is of course impossible to cover every possible condition, and as a consequence in some commercial designs the cost is carried to an extreme for the sake of a few watts gain in iron loss. This method of considering the question assigns to transformers designed for low iron loss at the expense of low initial cost and good regulation, the highest place for economy. That the method and conclusions are wrong, the following discussion will show.

Consider the effect of iron and copper losses on the lighting station and customer, and compare the results with what would occur were there no losses.

The iron loss of a transformer has a negligible effect on its secondary voltage. This means that if it becomes zero, the copper loss remaining constant, the customer's meter would still read the same for the same condition of load. The loss in net revenue to the lighting station due to this cause is, therefore, equal to the cost of generation, and since in general the cost of station attendance is not affected by the magnitude of the iron losses their effect is manifest in the coal bill only.

Consider next the effect of copper loss, neglecting the self-induction of the windings and assuming that the primary voltage be kept constant because of the obvious impossibility of the station attendant keeping the secondary voltage constant when transformers carrying various loads are supplied from the same circuit.

To take a specific example, let a transformer be used to operate a number of lamps representing an aggregate load of 1 000 watts at an e. m. f. of 100 volts, this being the secondary e. m. f. of the transformer at no load.

First of all consider the transformer as having no copper loss. This case is represented diagrammatically in Fig. 1, and the following values hold:

Resistance of load=10 ohms.

Secondary current=10 amperes. Power registered=1 000 watts.

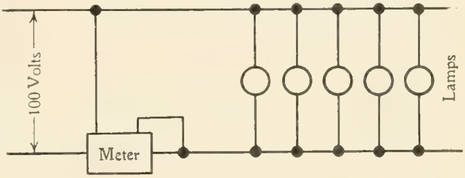


FIG. 1

Next consider a transformer having iron loss and copper loss each 3 per cent. of the rated capacity. Without altering the problem the copper loss may be considered as existing outside the transformer windings and be represented by the loss in a resistance (R_1) in series with the lamp circuit inserted between the customer's meter and the secondary terminals on that side of the circuit. This is represented diagrammatically in Fig. 2.

Since a transformer is rated on the supposition that the secondary e. m. f. is kept constant at all loads, $(R_1)=3$ ohms, and therefore in the case represented by Fig. 2 where the induced e. m. f. is 100 volts, the

Total resistance of secondary circuit........ =10.3 ohms
Voltage across meter shunt.................. =97.078 volts
Current in secondary....................... =9.71 amperes
Power registered in meter.................. =942 watts

Subtracting this latter value (942) from that which would occur if copper loss were zero (1 000), the

Reduction in meter reading due to copper loss
(i. e., decrease in voltage and decrease in current) ....=58 watts
Actual copper loss........................=28.3 watts
Power lost through decrease in current......=29.7 watts

The loss in net revenue to the lighting station through actual copper loss is evidently equal to the price at which the same amount of power could be sold to the customer; since were the copper loss zero this amount of power would be recorded in the meter. The loss in net revenue due to the decreased current is represented by power which is not generated, so that this power should be valued at the difference between selling price and its generating cost. And since the cost of station attendance will not be changed by variation in the copper loss of transformers the cost of generation will be equal to the value of the extra coal. Suppose, then, that the transformer supplies its load for 3 out of the 24 hours and let the cost per kw-hr in coal be ½ cent and the selling price per kw-hr 10 cents. A daily loss to the lighting station may be computed as follows:

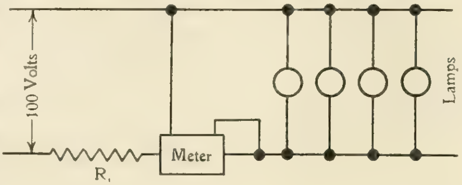


FIG. 2

(1)	30 watts iron loss for 24 hours or 0.72 kw-hrs at ½ cent=	.36 cents
(2)	28.3 watts copper loss for 3 hours or .085 kw-hrs at 10 cents=	.85 cents
(3)	29.7 watts loss of power for 3 hours, or .088 kw-hrs at 9½ cents=	.85 cents
	Total loss per day	2.04 cents

Compare this with the loss of income per day due to a transformer having the same full load efficiency but with iron loss and copper loss of 2 percent and 4 percent respectively, and supplying the same load of 1 000 watts.

(1)	20 watts iron loss for 24 hours or 0.48 kw-hrs at ½ cent=	.24 cents
(2)	37 watts copper loss for 3 hours or 0.11 kw-hrs at 10 cents=	1.11 cents
(3)	38.5 watts loss of power for 3 hours or 0.115 kw-hrs at 9½ cents=	1.09 cents
	Total loss per day	2.44 cents
	Total loss per day as computed above	2.04 cents
	Difference to lighting station per day	0.40 cents

This amounts to $1.46 per annum, and is the interest at 10 per cent. on $14.60.

Thus it is seen that the use of the transformer with the lower iron loss involves a direct loss to the central station of $1.46 per annum, but since the transformer having the lower iron loss is considerably more expensive than the one having equal losses, the interest and depreciation upon the difference of first cost should be added to the above loss, still further increasing the difference in favor of the transformer having equal losses.

The above example simply illustrates a rational method of viewing the transformer service. If this transformer were operated for a longer time per day or if a larger transformer were considered the net revenue would be greater.

When the load at different times varies, the following points should be remembered:

The load resistance varies inversely as the load.

The equivalent resistance due to copper loss is constant.

The per cent. copper loss varies directly as the load.

It is evident that as the load decreases the decrease in net revenue due to iron and copper losses becomes more nearly even.

It appears, therefore, that due to the large difference between the "selling price" and the "cost per unit of coal" the reduction in revenue due to copper loss outweighs the cost of coal for generating the iron loss. This leads to the conclusion that in general transformers designed with high all-day efficiency are not only higher in first cost but are more expensive to operate than those having equal iron and copper losses.

Moreover, what the customer desires is the maximum amount of light from a given amount of energy, with a reasonable length of lamp-life. This is obtained by keeping the full-load voltage on the lamps as near as possible to the no-load voltage, a condition which is obtained only with transformers having close regulations.

The following is a more general discussion of the question:

Let a transformer of capacity P be used to supply a number of lamps representing an aggregate load, P_1 at an e. m. f. E, which is the open-circuit e. m. f. of the transformer.

First, consider the transformer as having no losses.

This case is represented diagrammatically in Fig. 1:

Let $\frac{P_1}{P}=k$ then $P_1=kP$, and

Load resistance, $R_s = \frac{E}{P_1} = \frac{E}{kP}$

Secondary current, $I_s = \frac{P_1}{E} = \frac{kP}{E}$

Power registered, $P_1=kP$.

Now consider the effect if the transformer has copper loss mP, the primary e. m. f. being the same as before.

Without altering the problem the copper loss may be considered as existing outside the transformer windings, and be represented by a resistance R_1 in series with the lamp circuit inserted between the customer's meter and the secondary terminal on that side of the circuit.

The problem thus becomes the same as that of a transformer having no copper loss, operating a load having resistance $R_s + R_1$ as shown diagrammatically in Fig. 2.

The effects of copper loss in a transformer are therefore:

(1) Less current flows through the circuit than if there were no loss, or I_s is less than I_0, I_s being the secondary current in the case represented by Fig. 2.

(2) This current produces a drop in the voltage across the meter shunt terminals equal to $R_1 I_s$.

Thus we have two causes of decrease in meter reading due to copper loss:

(1) Power not generated due to loss of current or $P_t = (I_0 - I_s)$ E.

(2) Power dissipated through resistance of the windings or $P_s = I_s^2 R_1$.

Since a transformer is rated on the supposition that the secondary e. m. f. is kept constant at all loads:

$$R_1 = \frac{mP}{I^2} = \frac{mE^2}{P}$$

$$R_s + R_1 = \frac{E^2}{kP} + \frac{mE^2}{P} = \frac{E^2}{kP}(1+mk)$$

Therefore in the case represented in Fig. 2 where the primary e. m. f. is kept constant we have—

Secondary current, $I_s = \frac{E}{(R_s + R_1)} = \frac{kP}{E(1+mk)}$

Power recorded in meter, $P_m = I_s^2 R_s = \frac{kP}{(1+mk)^2}$

E. m. f. at meter shunt terminals, $= \frac{P_m}{I_s} = \frac{E}{(1+mk)}$

Copper loss of transformer, $P_s = I_s^2 R_1 = kP. \frac{mk}{(1+mk)^2}$

Decrease in meter reading due to copper loss is therefore:

$$P - P_m = kP - \frac{kP}{(1+mk)^2} = \frac{mk^2P(2+mk)}{(1+mk)^2}$$

Subtracting from this the copper loss P_s gives us:

$$P_t = (P - P_m) - P_s = kP.\frac{mk}{(1+mk)}$$

The loss in net revenue to the lighting station through P_s is evidently equal to the price at which the same amount of power could be sold to the customer; since were the copper loss zero, this additional amount of power would be recorded in the meter.

P_t represents power not generated so that the loss in revenue is equal to the difference between its selling price and cost of generation. Since, generally speaking, R_1, and therefore P_t, being zero, would involve no increase in cost of station attendance, the cost of generation will be equal to the value of the extra coal consumed.

To summarize:

In a transformer of capacity P, having iron loss nP and copper loss mP, used to operate a number of lamps representing an aggregate load, $P_1 = kP$ the factors that cause loss in net revenue are:

(1) nP iron loss chargeable at cost per unit of coal.

(2) $P_s = \frac{kP.\ mk}{(1+mk)^2}$ copper loss chargeable at selling price per unit.

(3) $P_t = \frac{kP.\ mk}{(1+mk)}$ chargeable at the difference between these prices.

Thus, if during a period of time T, this transformer is operated for lengths of time t_1, t_2, t_3 on a number of lamps representing at the open circuit e. m. f. of the transformer, loads $k_1 P$, $k_2 P$, $k_3 P$ respectively, the energy lost through:

Iron loss is nPT.

Copper loss is $\Sigma[P_s\, t] + \Sigma[P_t\, t]$ or

$$\frac{t_1 k_1 P.\ mk_1}{(1+mk_1)^2} + \frac{t_2 k_2 P.\ mk_2}{(1+mk_2)^2} + \frac{t_3 k_3 P.\ mk_3}{(1+mk_3)^2} +$$

$$\frac{t_1 k_1 P.\ mk_1}{(1+mk_1)} + \frac{t_2 k_2 P.\ mk_2}{(1+mk_2)} + \frac{t_3 k_3 P.\ mk_2}{(1+mk_3)}$$

If the portion of the above energy lost through P_s, viz., $\Sigma[P_s\, t]$, be called A, and the portion due to P_t, viz., $\Sigma[P_t\, t]$, be called B, and if C_1 and C_2 be the selling price, and cost per unit of coal respectively, then loss of income to lighting station during time T through transformer losses is:

$$nPT\, C_2 + A\, C_1 + B\, (C_1 - C_2)$$

These equations furnish a means of comparing the economy of transformers having different relations of copper loss to iron loss.

In the old method of considering the problem nP and P_s have been considered as both chargeable at cost per unit of coal. P_t has been entirely ignored.

THE STATUS OF WIRELESS TELEGRAPHY

By S. M. KINTNER

THE present status of wireless telegraphy is not very thoroughly understood by the engineering profession at large. So many wonderful things have been promised which have been slow in coming, and so many controversies have arisen among the workers in this field, that the average busy engineer has not had the time nor patience to follow all the ins and outs in the development of this new science.

It is the purpose of this article to discuss quite briefly the essential elements of wireless telegraphy and to indicate the state of the art at the present time.

Fundamentally, all telegraph systems consist of means of calling, sending and receiving. The calling and sending apparatus usually being the same, though there may be some difference at the receiving station between the apparatus used for receiving a call and that for receiving a message.

The necessary elements of the sending station of a wireless telegraph system are as follows: A spark gap, one side of which is connected to ground, the other to a vertical wire carried to a considerable height; an induction coil, or transformer, for producing a voltage sufficient to send sparks across the above mentioned spark gap; a source of current supply, such as batteries, or dynamo; and some suitable means of interrupting and making the circuit readily for the purposes of signaling. At the receiving station the essential elements are: A vertical wire connected to earth, but having in its circuit a wave detecting device, and such accessories as are required by the wave detecting device to operate it. For a complete station, consisting of both sending and receiving apparatus, the one vertical wire is used both for receiving and sending. This double use of the vertical wire necessitates the use of certain switching arrangements connecting either the sending or receiving apparatus according as to which it is desired to use.

Signals are sent by causing a stream of sparks to pass across the air gap, a great number of sparks representing a dash and a small number a dot, etc., as in the Morse code of signals. When the voltage begins to increase across the gap, for each individual spark, the voltage of the vertical wire is raised correspondingly, finally the voltage breaks across the gap and the charge residing in the vertical, and an equal amount on the earth, of opposite sign, oscillates back and forth across the gap at a very great rate. This oscillation of an electric charge sends out electro-magnetic waves. These waves are not directed, but go out sliding over the surface of the earth and increasing in height as they get farther from the source of disturbance. Every vertical conductor in the path of these waves will have oscillating currents set up in it of the same frequency as the sending source, and if a suitable detecting device is placed in series in the vertical conductor, the combination would serve as a receiving station of wireless messages.

All systems in operation at present, use the spark gap as their means of generating waves of sufficient rapidity of oscillation to serve the purpose at hand, though there have been proposals to build alternators giving one hundred thousand or more cycles per second, and allow them to operate directly on the vertical, one side being grounded. This method, with machines of sufficient frequency, giving sine wave voltages, should prove better than the present spark gap arrangement.

While several companies have made claims of ability to work with verticals only three or four feet high, the fact that none of them are so operating, in any of their permanent installations, is strong evidence that the tall antennae (as the verticals are called from the similarity to the antennae or "feelers" of insects) are still a necessary and expensive part of the equipment.

Most of the systems are using some form of a coherer at the receiving end for responding to the electric waves from the sending station. There are, however, one or two notable exceptions to this. The coherer, consisting, as it must from the very principle of its operation of a great number of loose contacts, generally between metallic filings in a glass tube, is a very treacherous device. It might be well looked upon as a trigger controlling the energy of a local battery circuit; when the oscillating currents coming in from the antennae "trip" it, by causing little sparks to fuse the bad contacts between filings, the local battery sends current through it, and some indicating device such as a telegraph sounder makes known the change of condition of the coherer due to the electric waves. The coherer must be tapped mechanically to restore it to its former condition, ready for the next signal. The exceptions to the coherer receiver are the "liquid barretter" of Fessenden's invention; and the magnetic detector, dependent on the sensitiveness of a sample of iron going slowly through its hysteresis cycle, to any change in its magnetizing force. This last named device is quite sensitive, and as an invention is claimed by a number of the various workers in this field. The "liquid barretter," mentioned above, is perhaps the most satisfactory detector, all points considered, yet produced. It is extremely sensitive, very regular in its action and not at all subject to injury from mechanical shock, vibrations, etc. The instrument consists of a piece of silver wire with platinum core, the core being only about $\frac{1}{10000}$ of an inch in diameter, dipping into a solution of nitric acid, the wire forming one terminal of the device. The acid is generally held in a platinum or gold cup—the cup forming the other terminal of the circuit. The indications are read by shunting a telephone receiver and local battery around the barretter, and then the flutter of the sending spark is accurately reproduced in the telephone receiver. So accurate is this reproduction, that no difficulty is experienced in distinguishing between sparks from two different sources, even though both are being operated at the same time. In the absence of non-interfering systems, this is a very valuable feature.

One of the greatest difficulties encountered in the operation of wireless telegraphy has been the interference produced by one set of stations upon another. That is when two stations are sending at the same time a receiving station within the range of both of the sending stations would receive both messages simultaneously and unless some peculiarity of the wave detecting device would allow the operator to pick out one set only of the two, the composite message would be unintelligible. Russia, in her use of wireless in the war with Japan, is having trouble from this cause at the present time, according to press reports.

The methods proposed for the eliminating of interference have nearly all been based on "tuning" or syntonizing the circuits.

By syntonizing is meant adjusting the relations between the inductance, resistance and capacity of the receiving circuit so that the natural period of oscillation of a charge set free to oscillate in it would have the same frequency as that of the sending circuit. Such a relation between the two stations of a wireless telegraph system is analagous to the well known response of a particular piano string, responding to the same tone that it gives when struck, if such a tone is sounded in the room with it on some other instrument.

In order to produce perfect syntony it is necessary to use a sine wave as a radiating electro-magnetic wave, and these are not easily produced. It is much easier to send out from the ordinary sending apparatus an unknown chord instead of the desired monotone. Then, also, the nearness of the conflicting stations, even though out of syntony, has considerable to do with the perfectness of the non-interfering operation.

There is a possibility that some form of synchronizing groups of circuits of various combinations may be a successful solution of this trouble. Several investigators are now working along this line. But at this writing no system in the market is strictly a non-interfering one. By a non-interfering system is meant one which cannot be interfered with by others sending at the same time.

The accompanying diagrams represent typical methods of connecting up the essential elements of the sending and receiving circuits. No effort is made to show the switching details, etc.

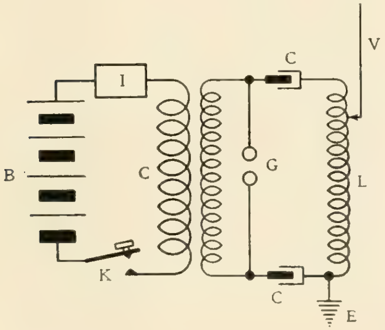


FIG. 1—SENDING STATION

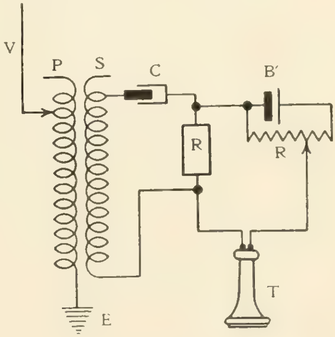


FIG. 2—RECEIVING STATION

In the diagrams V represents the vertical wire, which for a transmission of 200 miles, would likely be 150 feet high. It may consist of a single wire or of a number of wires, but for best results the vertical must be as nearly uniform throughout its entire length as possible, otherwise reflections will take place from points where the character of the vertical is changed.

The sending station in the diagram takes its energy from batteries B and the current passes through an interrupter I and its accessories, then through the primary of the induction coil to the switch K and back to the battery. The switch K is the point from which the operator manipulates the system in sending. As long as K is held down a stream of sparks will pass across gap G. Each discharge across the gap G consists of a number of oscillations due to the local circuit made up of condensers C C and inductance L, and such an arrangement tends to prolong the oscillations. The frequency of these oscillations is controlled by adjusting the values of C C and L. The inductance L acts on the verical V and earth as another oscillating circuit, L being an auto-transformer. The best action is gotten when these two circuits are adjusted so that they both have the same natural period of oscillation.

The receiving circuit also consists of two oscillating systems which must each be adjusted to the same period of oscillation as the sending circuit. Such a system would be a tuned one, and the oscillations set up in the receiving circuit containing the responding device R would be feeble for all waves sent out from sending stations of different periods of oscillation. The responding device simply produces a changed condition in the local circuit through it, the telephone receiver and source of constant voltage, such as the drop along a resistance wire shunted around the battery, when the local circuit has oscillations set up in it due to electro-magnetic waves coming from the sending station. In this way, by the flutter or click in the telephone, according to the character of the responding device used, the message is taken by the receiving operator.

There are many interesting problems to be worked out in this new science and a great amount of good substantial engineering to be done to put it on the plane it deserves. Now that the spectacular days are over and the public ceases to be thrilled by accounts of messages sent 200 miles or more, some more substantial developments may be expected. Its natural field is the sea, and there is where it will most likely be used to the greatest extent and the wires will continue in service on land.

The difficulties attending the commercial operation of the trans-Atlantic station have doubtless proven too great in the present state of the art, and little is heard of them now.

To fully appreciate the wonders of this new science, one must sit and listen to the dots and dashes being sent by some one perhaps two hundred miles at sea and experience the weird sensation of a first wireless telegraph message.

THE HUNTING OF ROTARY CONVERTERS

By F. D. NEWBURY

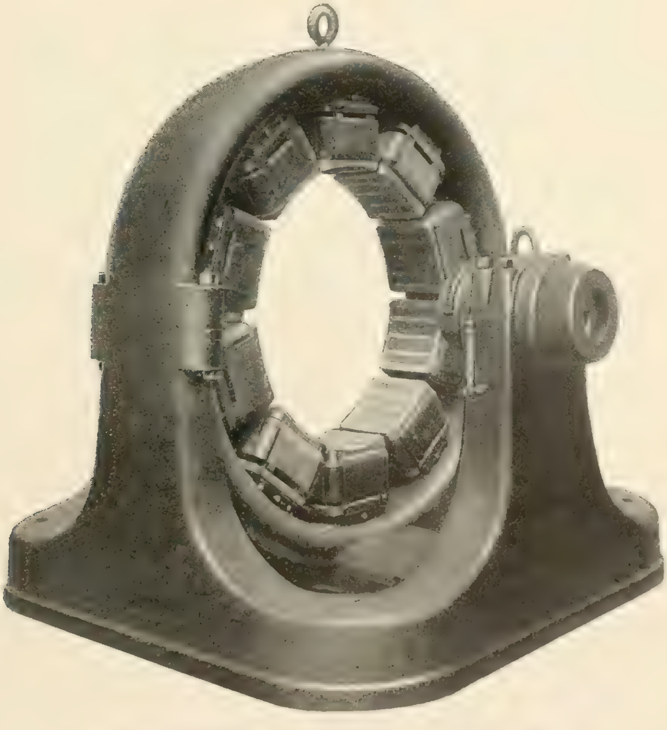
A ROTARY CONVERTER and the generator supplying it with power are, in the speed relations of the two machines, similar to an engine flywheel driving a second flywheel by means of a flexible coupling in which the driving force is transmitted through spiral springs. In this analogous mechanism the rotation of the second flywheel will be steady only as long as the rotation of the engine flywheel will produce exaggerated fluctuations in the rotation of the driven wheel, due to the flexible nature of the coupling between the two wheels. The action of this mechanism may be explained more in detail as follows:

If the engine flywheel momentarily increase its speed the second wheel will not maintain the same position relative to the engine flywheel as would be the case with two wheels rigidly connected together. The inertia of the driven wheel will cause it to lag behind the other in relative position until the resulting tension in the springs is great enough to overcome the inertia and momentarily increase its speed, bringing it back to its previous relative position. At the same time the tension in the springs reacts upon the engine flywheel so that the speed of this wheel is momentarily decreased if the engine will permit of a reduction in speed. If the inertia of the driven flywheel is large, the springs may take it beyond its initial position to a position relatively ahead of that of the engine flywheel, in which case the springs will be compressed, causing the second wheel to fall behind again, thus starting an oscillation in the rotation of this wheel. To set up this oscillation, three conditions are necessary: first, a variation in the regularity of the rotation of the engine flywheel; second, a flexible connection between the two wheels, and third, inertia in the second wheel.

In the electrical machines the action is very similar. If there is any irregularity in the rotation of the generator, the inertia of the rotary converter armature prevents it from instantly following the generator and the resulting difference in the relative positions of the two armatures causes a change in the phase positions of the generator e. m. f. and the converter counter e. m. f. This change in phase positions causes a difference in the instantaneous values of the two e. m. f.'s which, in turn, causes a so-called corrective current to flow between the two machines. This current in the electrical circuit is equivalent to the tension in the coupling springs in the analogous mechanical arrangement. When the converter armature is behind the generator in relative position, the corrective current flows in such a direction as to accelerate the converter armature and to retard the generator; it may also accelerate the converter armature too much so that from being behind the generator in relative position it is ahead of the generator. In this case a corrective current flows in the opposite direction, analogous to compression in the coupling springs, which retards the converter armature. In this way irregularities in the rotation of the rotary converter are produced which are not present in the rotation of the generator. This irregularity in the rotation of the rotary converter is called hunting. Hunting, as here described, is due first, to irregular rotation of the generator; second, to the flexible nature of the electrical connection between the generator and converter; and third, to the inertia of the rotary converter armature.

Due to the action of the corrective currents the rotary converter automatically tends to follow changes in the rotation of the generator. How closely it will actually follow the generator depends on the design of the rotary converter. If the self-induction of the armature be large, the corrective current for a given difference in e. m. f. will be small and the force tending to change the relative position of the converter armature will be less able to overcome its inertia. In this case the armature will be sluggish—it will not be able to follow the generator—so that the converter will fall out of step with relatively small changes in the relative positions of the two armatures. On the other hand, if the armature self-induction be small, the force tending to change the relative position of the converter armature will be greater than necessary, so that the armature will be carried beyond its proper relative position and an oscillation set up as already described. The armature with large self-induction corresponds with a coupling having weak springs, while the armature with small self-induction corresponds with a coupling having strong springs.

Corrective currents, due to a difference between the relative positions of the generator and converter armatures, increase the leading or lagging components of the total current, and these leading or lagging currents increase or decrease the strength of the generator and converter fields due to the magnetizing effect of these currents in the armature windings. Since hunting is an oscillation in the relative position of the converter—ahead of the generator at one instant and behind it the next—the corrective currents in the circuit due to this oscillation are first in one direction and then in the opposite direction. The effect of this varying current is to strengthen one pole tip when flowing in one direction, and weaken the other pole tip when flowing in the other direction, thus continually changing the distribution of magnetism over to the pole face and, in effect, causing the magnetic flux to continually shift back and forth across the pole face. This occurs in both rotary converter and generator. This shifting of the magnetic field has an incidental effect, flashing occurs at the direct current brushes of the rotary converter whenever the armature coil in which the current is commutated is brought into a strong field by the shifting flux.



ROTARY CONVERTER FIELD SHOWING GRID DAMPERS

This fact, that hunting is always accompanied by a shifting field, makes possible an effective method of preventing hunting. The converter is provided with heavy copper grids that surround each pole face and extend across it imbedded in one or more slots. The form of these grids is shown in the photograph. The function of the copper grids is to act as dampers preventing the relative position of the converter armature from being changed by the corrective currents more than the initial change in the generator. The action is essentially a damping action and is the same as that of the copper-magnet damper used in galvanometers and is analogous to the action of a dash-pot on an engine governor. If all the coupling springs in the flywheel arrangement already considered were provided with dash-pots the controlling action of the dash-pots would tend to prevent the "hunting" of the driven flywheel.

To consider the action of the dampers in detail, assume that the generator speed momentarily increases. This causes a difference in the phase of the generator and converter e. m. f.'s. The difference in the instantaneous e. m. f.'s due to the difference in phase will cause a corrective current to flow in the circuit that will distort the fields and accelerate the converter armature. The shifting flux cuts the copper grid and generates in it eddy currents which retard the converter armature, i. e., the secondary eddy currents have an effect the reverse of that of the primary corrective current. The accelerating action of the corrective currents occurs as long as the converter armature is behind the generator, but the retarding action of the eddy currents lasts only while the relative positions of the converter and generator armatures are changing; i. e., while the magnetic flux is moving across the pole face. The eddy currents, therefore, do not act as a constant opposing force to the corrective currents, but as a true damping force, becoming zero whenever the generator and converter armatures revolve without changing their relative positions.

Up to this point a single rotary converter and generator have been considered. When two or more converters are connected to the same generator, hunting in one converter may cause trouble with other converters connected to the same circuit if the lagging and leading currents due to the hunting are large enough to produce serious pulsations in the generator voltage. Dampers on the generator field poles will help control the corrective currents flowing between the generator and hunting converter, the action of these dampers being identical with those on the rotary converter. For this reason a generator designed for the operation of the rotary converters is usually provided with dampers even if it is not to be operated in parallel with other generators.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS*

III—TRANSFORMERS

By V. KARAPETOFF

THE vector diagram of a transformer gives a clear picture of the performance of the transformer under different conditions of load. By means of the diagram the drop of voltage in a transformer for any given load can be predetermined with great accuracy. To furnish data for this diagram, two simple tests are necessary—a no-load test to determine the ratio and iron loss, and a short-circuit test to give the inductive drop. It is assumed that the ohmic drop has been determined in the usual way.

The following applications of the diagram will be considered in this lecture:

(1) Diagram of an ideal transformer.
(2) Influence of iron loss.
(3) Influence of copper loss and leakage flux.
(4) Approximate practical diagram of transformer.
(5) Experimental determination of inductive drop.
(6) Kapp's diagram for predetermination of drop and regulation.
(7) Diagram of auto-transformer.

(1) *An ideal transformer* may be called one (a) which is built of perfectly soft iron, possessing no hysteresis loss; (b) which has its iron so perfectly laminated as to have no eddy currents produced in it; (c) the ohmic resistance of both windings of which is negligibly small; (d) the primary and secondary coils of which are so closely interwound that there is no leakage flux.

The diagram of such a transformer is shown in Fig. 28. This diagram is based on the two fundamental physical facts: (1) Every magnetic flux is in phase with the current which produces it; (2) the induced e. m. f. always lags 90 degrees behind the magnetic flux inducing it. The first of these propositions is self-evident. Suppose an iron core to be magnetized by direct current. If the current be increased, the magnetism in the iron increases also; it diminishes if the current diminishes, and is reversed if the current is reversed. If direct current is changed periodically according to the sine law, it becomes an alternating current. Thus we may say that the flux changes periodically and in phase with the magnetizing current. The second proposition is an immediate result of the general law of induction, that the induced e. m. f. is proportional to the rate of change of lines of force through a loop of wire. At the instant when the flux attains its maximum there is no change in the number of lines for two consecutive moments; therefore the induced e. m. f. is zero. At the moment when the flux passes through its zero value its rate of change is greatest; accordingly the induced e. m. f. is then maximum. Thus when the flux is maximum the e. m. f. is passing through zero in the same direction, and when the flux in zero the e. m. f. has reached its maximum. Consequently, the e. m. f. lags 90 degrees behind the flux.

---

*A series of lectures delivered before The Electric Club.

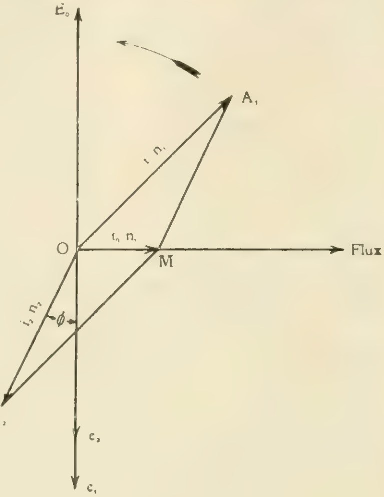


FIG. 28

In Fig. 28 the horizontal vector represents the magnetic flux of a transformer; e_1 and e_2 are the e. m. f.'s induced by this flux in the primary and in the secondary windings respectively. Both are lagging 90 degrees behind the flux.

Now $\frac{e_1}{e_2} = \frac{n_1}{n_2}$ where n_1 and n_2 are the corresponding number of turns in the windings. The applied e. m. f. is represented by vector E_0 equal and oppositely directed to e_1.

If primary voltage is kept constant, the secondary voltage is also constant (assuming an ideal transformer). The secondary current depends entirely upon the secondary circuit.

If the transformer has to deliver W watts at p per cent. power-factor, the secondary current can be found from the equation

$$W = e_2 i_2 \frac{p}{100} \text{ or } i_2 = \frac{W}{e_2 p} 100.$$

As was explained before, the flux and magnetizing current are in phase, so the primary ampere turns $i_1 n$ are composed of two elements: $i_0 n_1$, the magnetizing portion and MA^1, the working portion to balance $I_2 n_2$ in the secondary circuit.

The magnetizing ampere turns $i_0 n_1$ can be calculated from the magnetic resistance of the iron path as in direct-current apparatus.

$$\frac{4\pi}{10} i_0 n_1 = \Phi R.$$

where R is the magnetic resistance or reluctance of the iron.

In practice it is usually assumed that the currents in a transformer are inversely proportional to the number of turns in the windings, or, what is the same, to the voltages. This is very nearly true, because in good transformers the magnetizing current i_0 is very small compared to load currents, so that we can say

$$\frac{i_1}{i_2} = \frac{n_2}{n_1} = \frac{e_2}{e_1}$$

An example may show the application of the above diagram under the assumption that there are no losses.

Example—With the secondary circuit open the primary is connected to a source giving 1 100 volts. The following are the readings: Primary voltage 1 100 volts, secondary voltage 110 volts, primary (magnetizing) current 1.5 amperes. It is required to find the primary current at a small load of 3.5 kw, and a large load of 100 kw. The power factor of the load is supposed to be 80 per cent. in both cases. Fig. 29 shows the vector diagram.

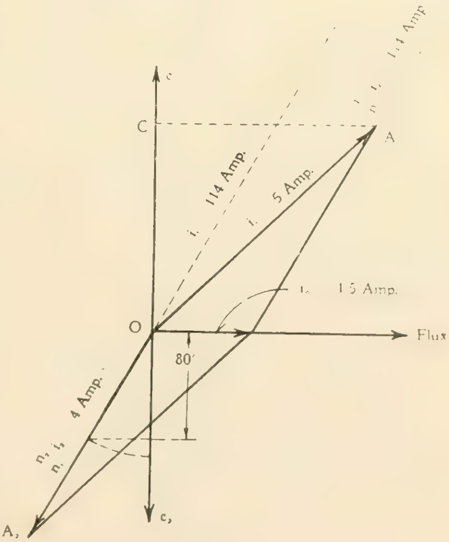


FIG. 29

In the first case the secondary current is

$$i = \frac{3500}{110 \times .80} = 40 \text{ amperes.}$$

This reduced to the primary circuit by the usual method gives 4 amperes of load current. Completing the parallelogram (Fig. 29), we find $i_1 = OA_1 = 5$ amperes, and dropping perpendicular A_1C, we find power factor as $\frac{OC}{OA_1} = 64\%$. For the load of 100 kw the secondary current is $i = \frac{100{,}000}{110 \times .80} = 114$ amperes. The directions of the sides of the parallelogram are shown in Fig. 29 by dotted lines. It is evident from the figure that practically both sides may be assumed as equal and parallel, so large is 114 as compared with 1.5. Therefore the primary current is very nearly 114 amperes, and the condition $i_1 n_1 = i_2 n_2$ is satisfied. We purposely selected a small load and a normal one to show that relation $i_1 n_1 = i_2 n_2$ is only satisfied if the magnetizing current is small compared with working current. Practically, in good transformers the ratio of currents is very nearly the ratio of the number of turns unless the load is under 20 per cent. of full load.

This should be borne in mind, especially in the application of transformer diagrams to induction motors, which in some respects are like transformers, as the primary currents in the stator induce currents in the rotor as a secondary. But the magnetizing current is, comparatively, much larger than in transformers, due to the air gap.

(2) *Influence of Iron Loss*—Each periodical magnetization of iron demands a certain amount of energy to overcome losses due to hysteresis and Foucault currents. In the diagram of Fig. 28 it was supposed that the magnetizing current was a wattless current lagging 90 degrees behind the e. m. f. In reality, besides this component OM, another component MM^1 (Fig. 30) is necessary to overcome the iron losses. Consequently, the total no-load current OM^1 is somewhat leading the magnetic flux instead of coinciding with it as would be the case with ideal iron or in transformers without iron, such as the high-frequency transformers used in wireless telegraphy. In other respects Fig. 30 is the same as Fig. 28, as shown by dotted lines.

If desired, the component MM^1 of the magnetizing current may be assumed to flow through a special winding in parallel with the actual primary winding of the transformer. In this way the iron loss can be replaced by a copper loss in this imaginary winding. The diagram remains, of course, the same; current OA_1 flowing through the transformer, current MM^1 flowing through the imaginary external winding. Their sum OA_1 is supplied from the line.

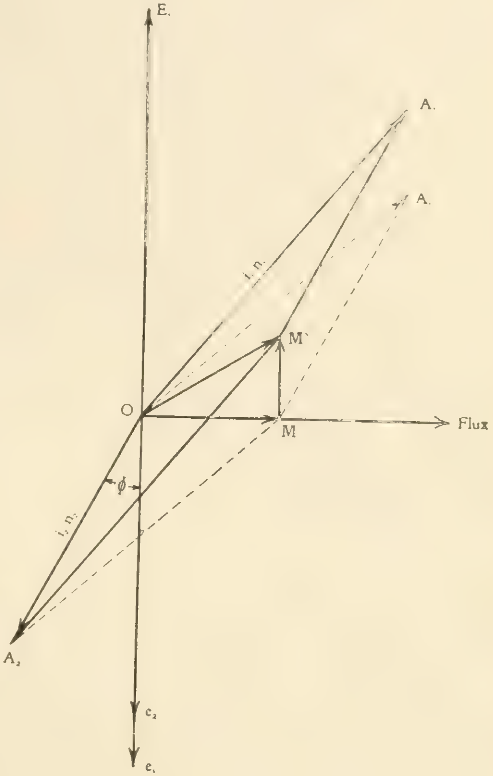


FIG. 30

(3) *Copper Loss and Leakage*—The terminal pressure on the primary of a real transformer has not only to balance the counter e. m. f., induced by the magnetic flux, but also has to be in excess of it to overcome the ohmic resistance of the primary winding and the inductive resistance in it caused by the magnetic leakage.

Leakage in transformers is produced by a certain number of magnetic lines not being interlinked with both primary and secondary windings. The amount of this leakage is very small in good modern transformers because the primary and secondary windings are interlaced in several layers. This leakage, however, cannot be completely obviated. The leakage lines of force induce a counter e. m. f. in the primary which is not transmitted in the secondary and so

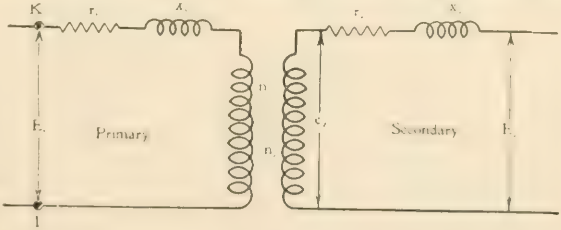


FIG. 31

causes a loss of voltage, much like the loss of voltage due to the ohmic resistance of the primary winding. The same two causes also diminish the secondary terminal voltage. To take these losses into account, imagine the transformer itself as an ideal transformer but having connected in series with it an ohmic resistance equal to that of the actual transformer and a choke coil possessing an inductive resistance equal to that due to leakage flux of the transformer (Fig. 31).

The corresponding complete diagram of the actual transformer is shown in Fig. 32. As before $OB_1=e_1$ and $OB_2=e_2$ the induced e. m. f.'s in primary and secondary. OA_1 and OA_2 are the currents. The pressure e_1 applied between the points K and L (Fig. 31) has to be larger than e_1 by an amount necessary to overcome the ohmic drop in r_1 and the inductive in x_1. The ohmic drop is represented by the vector $B_1 C_1=i_1 r_1$, parallel to the primary current i_1. The inductive drop is represented by $C_1D_1=i_1x_1$, perpendicular to i_1. The applied e. m. f. E_1 is $O\ D_1=O\ B_1+B_1\ C_1+C_2D_2$ by geometrical addition.

In a similar way the ondary terminals is less than the induced e. m. f. e_2 by the amount lost in the secondary resistance r_2 and inductance x_2. These losses are represented on the diagram by the vectors $C_2\ B_2=i_2\ r_2$ and $D_2 C_2=i_2\ x_2$ respectively parallel and perpendicular to the secondary current. The resultant secondary voltage is $E_2=O\ D_2=O\ B_2-C_2\ B_2-D_2\ C_2$ by geometrical subtraction.

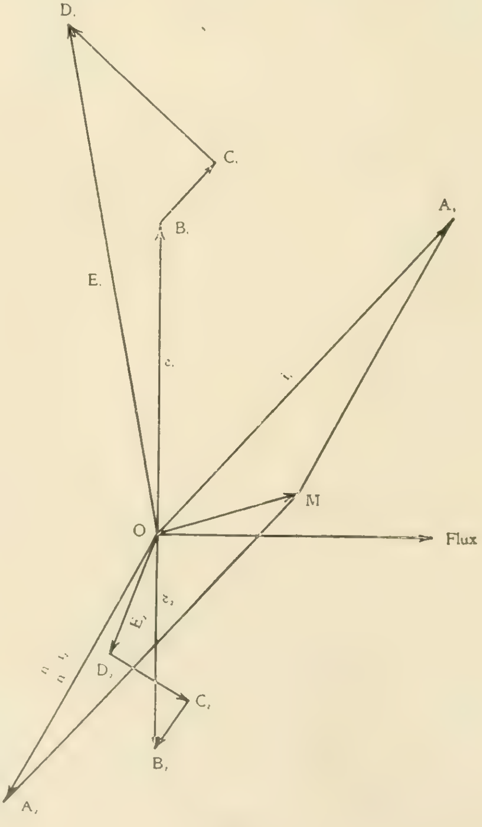


FIG. 32

Fig. 32 shows a complete diagram of a transformer in which iron losses, copper losses and magnetic leakage are taken into account. It is evident that with an actual transformer a higher primary voltage must be applied than would be necessary if there were no losses. On the other hand a given primary voltage gives a lower secondary voltage than an ideal transformer. In this way we come to the conceptions of *drop in a transformer and regulation of a transformer.* Suppose, for instance, the ratio of a transformer to be 1 000 to 100—that is, at no-load 1 000 volts on the primary gives 100 volts on the secondary. At full non-inductive load the same 1 000 volts on the primary will give only, say, 98 volts on the secondary. It is then said that the transformer has a drop of 2.04 per cent. at full non-inductive load. Both primary and secondary drop is included in it.

If, at 80 per cent. power factor, the same transformer gives 97 volts secondary at full load, then it is said that the regulation of the transformer is 3.09 per cent. at full load and 80 per cent. power factor. These percentages are based on the full-load values of secondary voltage.

In giving guarantees for drop or regulation, it is very important to state clearly for what power-factor these guarantees are given. It is easy to see from Fig. 32 that the smaller angle of lag $D_1 O A_1$ is, the nearer to a right angle OD_1C_1 becomes, and the less effect $D_1 C_1$ has in reducing the value of E^1. The cosine of angle $D_1 O A_1$ is the power-factor at which current is being delivered to the transformer. Therefore, a larger leakage may be allowed in a transformer that is expected to work on an incandescent light load than on one that must work on a load consisting of both light and power. The inductive drop being at right angles to the current on the lighting load, it has but little effect.

THE FIRST AID TO THE INJURED[*]

By IRA N. FIX, M. D.

WHEN an injury occurs through some accident the future welfare of the injured person depends largely on the immediate aid which can be secured before the arrival of a physician. The purpose of this paper is to give an outline of the general procedure for cases where the nature of the injury is not clear.

Assume that an accident has occurred.

If possible first secure a stretcher, place the patient upon it, removing him from the cold floor, and wrap him in the blankets attached to the stretcher. This is done because every case of accidental injury is accompanied by shock, which is a condition of vital depression and which may be of any degree of intensity, from a slight, evanescent and hardly appreciable disturbance of the mental force, to the most profound depression and speedy death.

The symptoms of shock are those of general depression; the skin is pale and cool, the pulse is feeble and rapid, the breathing is shallow and irregular, the bodily temperature is lowered, a sense of faintness is felt by the individual; or if the shock is great, total loss of consciousness occurs. The functional activity of all the organs of the body is interfered with and there is a sense of muscular powerlessness.

Having cared for the patient regarding shock, examine him for objective injuries. Suppose a wound is found which is bleeding freely from a severed vein or artery, how shall the bleeding be stopped? There are two forms of hemorrhage, arterial and veinous: the former from a severed artery, the blood coming from the heart, necessitates the placing of the constriction between the wound and the heart; while the latter, being a vein in which the blood is flowing from the extremities to the heart, the constriction is placed between the wound and the extremity.

As soon as the hemorrhage is controlled the wound must be dressed with clean cloth or cotton. This done, the preliminary work is finished. The habit of covering a wound with shellac, or the abominable practice of placing filthy tobacco on the wound should never be allowed, as the wound is infected and the person is liable to be inoculated with syphilis or similar diseases.

---

[*] An Abstract of a lecture Before *The Electric Club*

In case a fracture of a limb is discovered, whether simple or compound, the first requirement is to hold the broken member quiet in order to prevent the ragged ends of the bones from tearing the tissues. This is accomplished by application of a splint, which may be a board of suitable dimensions, or anything available to which the limb can be rigidly fastened.

Injuries of a different and more serious nature which will next be considered are those resulting from burns. In these cases we find the conditions of shock most pronounced and the suffering most acute, yet the treatment is best defined. In all cases of burns the air must be excluded from the burn by applying any heavy oil dressing, the most effectual being linseed oil, or still better, equal quantities of linseed oil and lime water applied on soft muslin and covered with a thick layer of cotton.

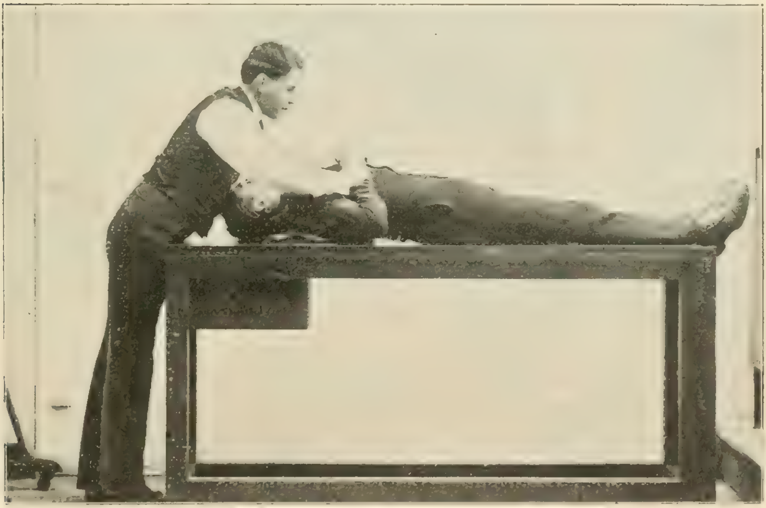


FIG. 1—ARTIFICIAL RESPIRATION—FIRST POSITION

A class of cases which occasion a great deal of excitement and for which very little can be done are those where the patient loses consciousness without any apparent reason. There are a number of troubles which will cause this condition, and it requires one educated in diagnosis to differentiate between them. The person may have fainted, he may have had an epileptic seizure or a stroke of apoplexy, it may be acute alcoholism, or he may have received an electric shock.

If it is certain that it is not a case of electric shock, proceed exactly as under conditions of surgical shock already considered. However, if any suspicion of electric shock is entertained, the patient should be immediately placed in position for artificial respiration, preferably on a table with a cushion under his shoulders to elevate them slightly. Then bring his arms down until his hands rest on his chest, grasp his wrists and press firmly against the lower walls of the chest for a few seconds, then raise the arms outward and upward until the hands meet, drawing firmly upward for a few seconds; repeat this procedure ten or fifteen times a minute. The two extreme positions are shown in the two photographs. The efforts of resuscitation must be continued for an hour or more, with stimulants used hypodermically and with artificial warmth. Unfortunately we are not always able to secure the results we seek, but efforts should be continued as long as life remains.

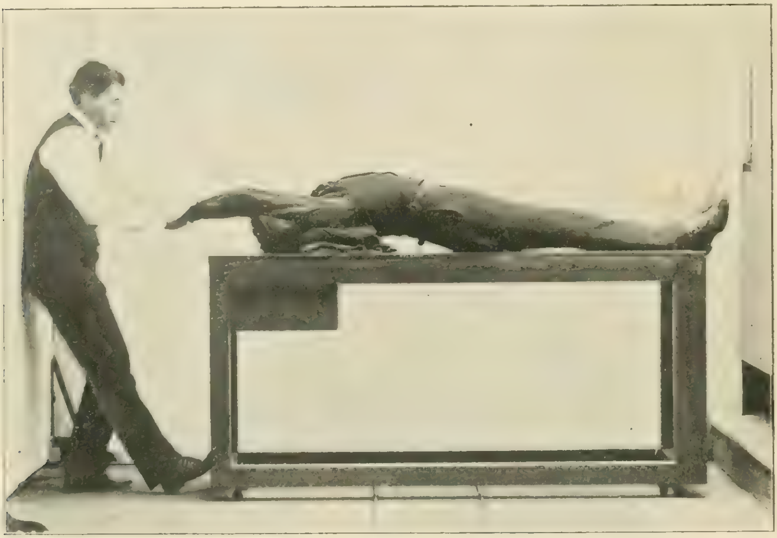


FIG. 2—ARTIFICIAL RESPIRATION—SECOND POSITION

(B) REGULATION TEST BY LOADING BACK METHOD

FACTORY TESTING OF ELECTRICAL MACHINERY—V

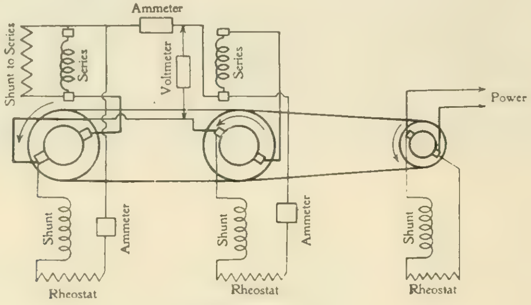
By R. E. WORKMAN

(b) Regulation Test by Loading-Back Methods:

(1) Where a motor is obtainable of a capacity equal to or greater than that of the generator to be tested. A driving motor of sufficient capacity to supply the full load losses of the two other machines is also required.

Preparations for Test—The three machines are belted together and the connections made as shown in Fig. 23. As the machines which are loading back on one another are practically running as generators in parallel, with currents circulating in their armatures due to differences in the e. m. f.'s induced, it is necessary for stability that their e. m. f. characteristics should be similar. Thus, if a shunt-wound generator is to be tested, it should be loaded back on a machine which is running as a shunt-wound machine. If a compound-wound generator is to be tested, it should be loaded back on a compound-wound machine. In this latter case it should be noted that the series coils of the machine which is to generate the lower e. m. f., which is practically to run as a motor, must be so connected as to strengthen the field with an increase in the load. This means that if the machine is connected for constant potential when run as a generator, its coils must be reversed before a generator can be loaded back upon it. The reason for this will be obvious if it is remembered that for the same polarity of field and the same direction of rotation in the same machine, the current in the armature will be in the opposite direction in a motor from what it is in a generator.

Conduct of Test—The main and field switches of the two machines are opened, the driving motor started from a panel or starting table and its speed adjusted so that the generator shall run at its designed speed. The brushes of the two machines must now be



Scheme of Connections

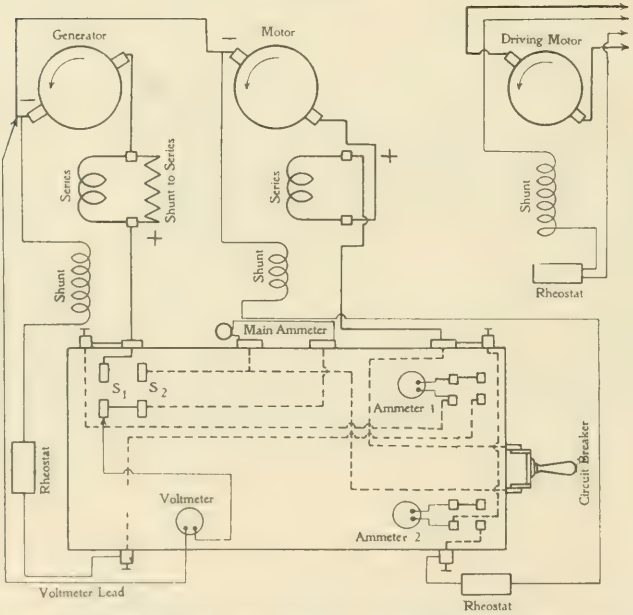


FIG. 23—CONNECTIONS FOR REGULATION TEST BY LOADING BACK METHOD

set on trial full-load positions, that of the machine to be tested in advance of the no-load neutral; that of the other machine, as it is to run as a motor, behind the no-load neutral position. The field switch of the generator under test may be closed and its voltage adjusted by means of the rheostat in its shunt field. The same may then be done in the case of the other machine. The voltage of the machines must be brought to exactly the same value and, this being done, the main switch closed, paralleling the two. While closing the switch the main ammeter should be watched carefully, as, if the series coils in one of the machines should be reversed, a very rapid rise in the current might be the result. If this should happen, the circuit breaker should at once be tripped, and the fault remedied.

As in the test with resistance load, the order of reading is:

(i) No-load reading to adjust shunt field resistance for proper terminal voltage at no load.

(ii) Full-load reading to adjust the resistance required on the shunt to the series winding.

(iii) Intermediate readings, all adjustments being left the same as in (ii).

The load is raised by weakening the field of the machine running as a motor.

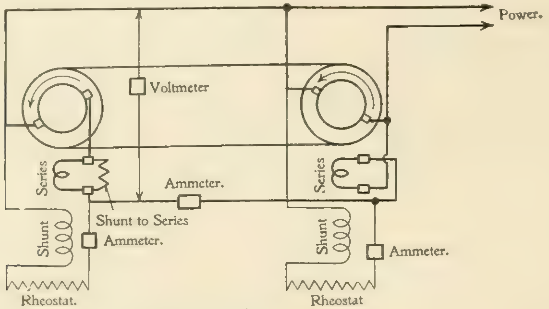
The speed is held constant throughout by adjusting the shunt field rheostat of the driving motor.

In the case of smaller machines, where the line voltage may be adjusted at will by means of a booster or by field regulation in the generator supplying the power, it is possible to make the regulation test without a driving motor. The two machines belted together are run in parallel across the lines. It will be seen that for certain values of the shunt currents, the two machines will run as motors, at a definite speed, without any torque between them. As soon, however, as the shunt current of one of the machines is increased, the conditions are altered. The machine whose shunt current has been increased will begin to act as a generator, and send current back to the line. The other machine, as it has to drive the one which is acting as a generator, will have its current increased, so that, virtually, current will circulate between the two machines just as in the last test.

Preparations for Test—The connections are made as shown in Fig. 24, and the brushes set on trial full-load position, as before. The same precautions must be taken to see that the series windings are working in the proper way.

Conduct of Test—The motor is started from a panel or starting table and brought to speed, all the generator switches being open. The generator shunt-field switch must now be closed, its voltage brought up and the two machines paralleled, as in the last test. The readings may now be taken in much the same way as before, the order being:

No-load reading, to adjust the shunt-field resistance, so that the machine shall give the proper voltage at no load. This may be done either before or after the machines are paralleled, the voltage being held at the proper value, the speed brought right by manipulating the shunt rheostat and the proper shunt resistance for the generator found.



Scheme of Connections.

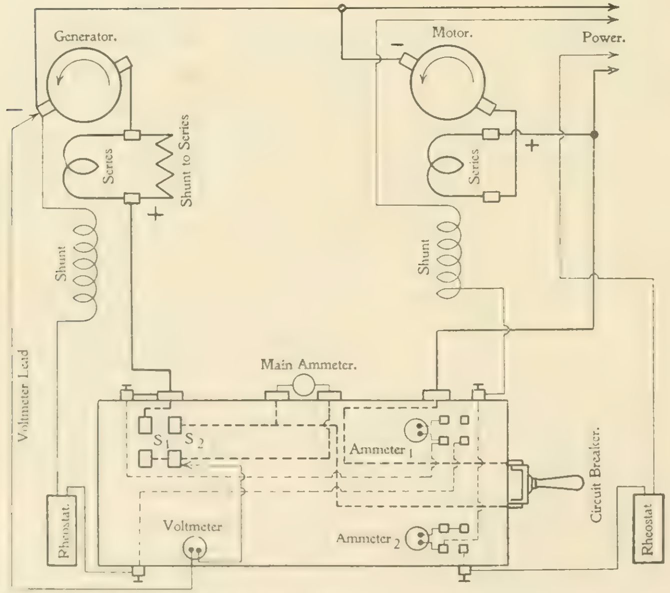


FIG. 21.—CONNECTIONS FOR REGULATION TEST BY LOADING BACK METHOD

Full-load reading to adjust the resistance of the shunt to the series winding.

Intermediate readings to determine regulation curve.

The set should be shut down by tripping the circuit breaker between the power and the motor.

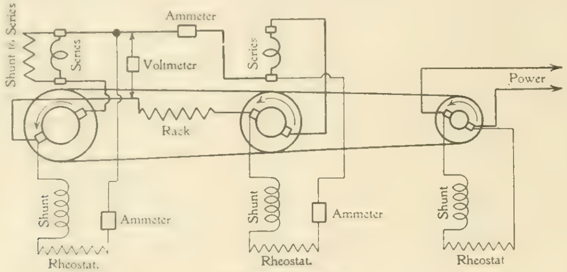
(2) When the generator has a voltage much higher than that of the only obtainable motor to run it with, but a similar current capacity, the last mentioned test requires to be amended. As the load of the generator is greater than the maximum permissible load of the motor, it becomes necessary to take up the excess by means of resistance in series with the machine.

Prparations fcr Test—The same table is used as in the last two tests, and the machines belted together in the same way. The connections are then made as in Fig. 25.

Conduct of Test—The driving motor is started up as before, the field switches and main switch of the two machines being open. The brushes of both generator and motor are set on trial full-load positions, their field switches successively closed, the voltage of the two machines brought as nearly equal as possible and the main switch closed. As before, the main ammeter should be carefully watched when throwing in the main switch, and if anything goes wrong the circuit breaker should at once be tripped. When the machines have been successfully paralleled the voltage of the generator may be brought to its correct value, while that of the motor is held as high as possible. The load is applied by decreasing the amount of rack resistance in the circuit (the reason for this is obvious if it is remembered that the effect of the rack is to compensate for the difference of voltage in the two machines by means of the drop of potential in its length. In order that the number of volts drop in the rack may remain similar when the load is increased, the rack resistance must evidently be decreased.) In order to fix the resistance required on the shunt to the series winding, it will be necessary to take successive readings of the full-load voltage and the voltage with the circuit open, as it is impossible to bring down the load to zero without opening the circuit. In shutting down, the driving motor may be stopped straight away by tripping its circuit breaker.

Precautions to be Observed—It is important that the load should be distributed between the motor and the rack so that the motor gets its maximum load. As little load as possible should be put in the rack, so that the driving motor input may be as small as possible. If the load on the machine running as a motor is too high it may be lowered by increasing its field current, the generator load being readjusted by decreasing the rack resistance.

(3) In the case of a generator having the same voltage as the machine with which it is to run, but a greater current carrying capacity than this machine, it is necessary to put a rack in parallel with the latter, in order to take up the surplus load.



Scheme of Connections.

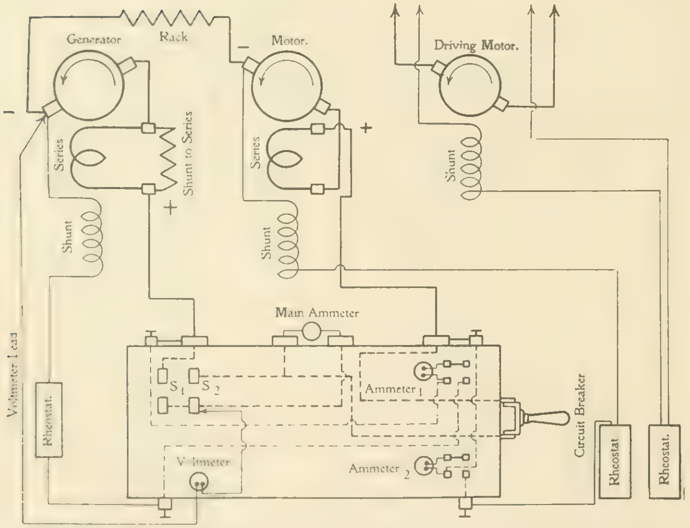
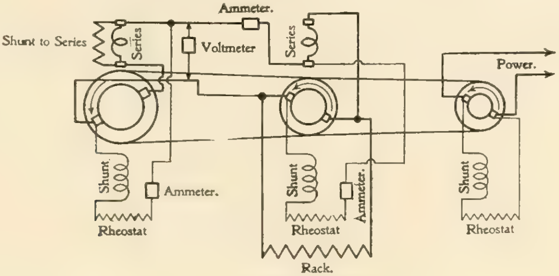


FIG. 25—CONNECTIONS FOR REGULATION TEST BY LOADING BACK METHOD

Preparations for Test—This test is carried out in exactly the same way as (1) except that the rack is used to prevent the overloading of the machine running as a motor. The connections are made as shown in Fig. 26.

Precautions to be Observed—The load must be properly distributed between the rack and the motor, as in the last test.

Working up Results—The results from the different methods are, of course, the same; they are taken directly from the readings, corrected for the calibration of the instrument. The following example will explain how the curves are plotted:



Scheme of Connections.

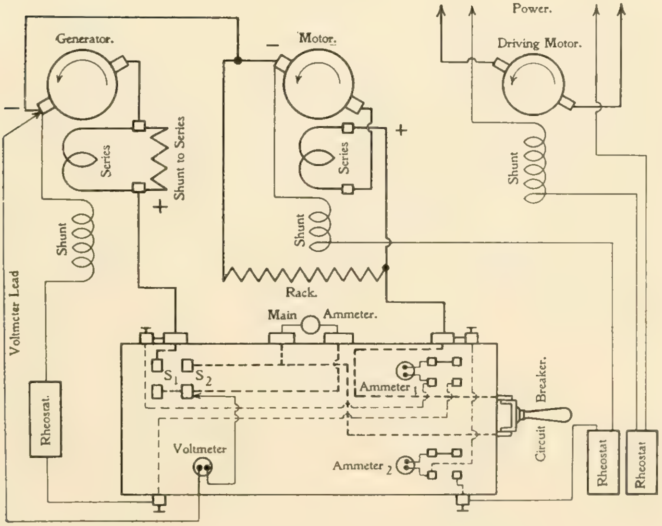


FIG. 26—CONNECTIONS FOR REGULATION TEST BY LOADING BACK METHOD

Example—The same machine as in the preceding tests—500 kw, 550 volts, 910 amperes, 514 r. p. m.

The following readings were obtained:

EXTERNAL AMPERES	TERMINAL VOLTS	FIELD AMPERES	SPEED
1137	535	4.56	514
910	550	4.68	514
682	548	4.68	515
455	543	4.63	514
627	531	4.51	514
0	500	4.28	514

The compounding required is such as to give 500 volts at no load, and 550 volts at full load.

These values are plotted in the accompanying curve, Fig. 27:

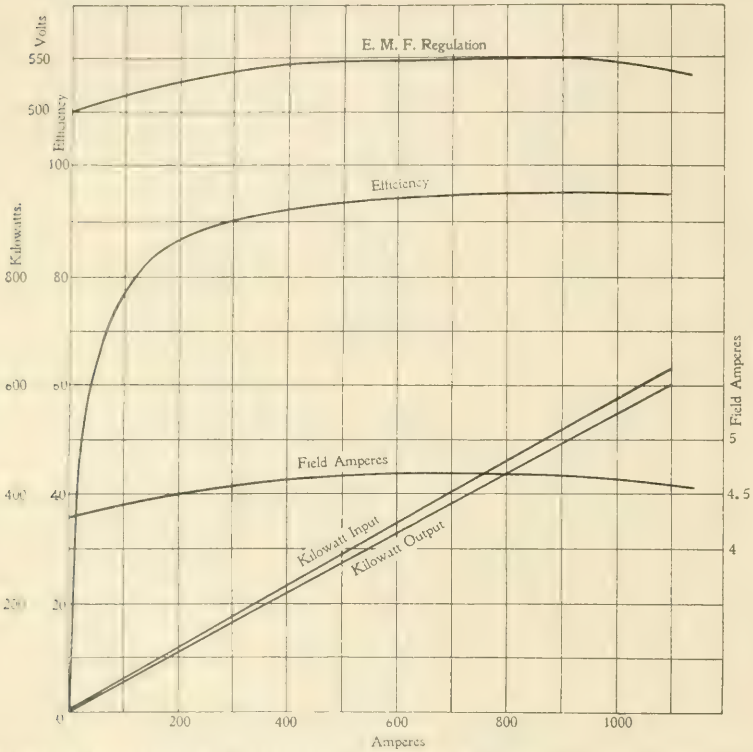


FIG. 27—REGULATION AND EFFICIENCY CURVES OF A DIRECT-CURRENT GENERATOR

EFFICIENCY FROM LOSSES—The foregoing tests serve as a basis for the calculation of the efficiency curve. This curve gives the relation of the efficiency to the external current of the machine. It will be sufficient to indicate the method of calculation for one point on the curve, say the full-load point. The 500-kw machine used above as an example will be that considered. The necessary data and steps in the calculations are given below with the actual figures for the full-load efficiency.

(1) External amperes—910 (full-load current).

(2) Terminal volts—550 (full-load voltage, taken from regulation curve for 910 amperes).

(3) Field amperes—4.68 (taken from regulation curve for 550 volts).

(4) Armature amperes—914.7 (external amperes + field amperes).

(5) Resistance of armature and series field windings—.0042 ohms (found as described below).

(6) Armature and series field copper loss—7880 watts [(armature current)^2 × resistance of armature and series field.]

(7) Shunt field and rheostat copper loss—2575 watts (external volts × field amperes).

(8) Brush I^2R loss—1670 watts (found as described below).

(9) Volts lost in armature and series field—8.61 (armature current × resistance of armature and series field).

(10) Volts lost in brushes, leads, etc.,—2 (assumed).

(11) Total volts induced in armature 560.6 [sum of terminal volts and lost volts = (2) + (9) + (10).]

(12) Iron loss—9505 watts (taken from iron loss curve opposite 560.6 volts).

(13) Brush friction—2530 watts (found in loss tests).

(14) Friction and windage—1980 watts (found in loss tests).

(15) Total losses—26.14 kilowatts [(6) + (7) + (8) + (12) + (13) + (14).]

(16) —Output 500 kilowatts (external amperes × terminal volts).

(17) Input 526.1 kilowatts (output + losses).

(18) Efficiency 95.2 (output ÷ input).

COPPER LOSSES

These are all taken at a temperature of 50° C.

The shunt to the series winding had a resistance of .00268 ohm.

Armature resistance reduced to its equivalent at 50° C.=.00833 ohm.

Series field resistance reduced to its equivalent at 50° C.=.00183 ohm.

Resistance of series field and its shunt, in parallel =

$$\frac{.00268 \times .00183}{.00268 + .00183} \text{ ohm} = .00109 \text{ ohm}.$$

Resistance of armature and shunted series field in series=.00942 ohm.

The copper loss in armature and series field is, therefore, $(914.7)^2 \times .00942 = 7880$ watts.

Brush I^2R Loss—This is found by the use of a formula determined by means of a series of exhaustive experiments. Though for any special form of brush or quality of carbon, it may give results different from the actual, a very good approximation is given when ordinary brushes are used. The formula takes the form of a relation between the current density in the brushes and the volts drop from terminal to terminal of the machine due to the brushes alone. The current density in the brushes for a given armature current is found by dividing the armature current by the area of half the total number of brushes, i. e., the area of the number of brushes in parallel. This is taken in amperes per square inch. The relation mentioned above is:

Up to ten amperes per square inch, current density, the drop for every ampere per square inch is .125 volts.

Above ten amperes per square inch, current density, the drop for every ampere per square inch is 1.25 volts + .025 volt for every ampere per square inch above 10.

DENSITY	DROP
5 Amperes per square inch	0.625 Volts
10 " " " "	1.250 "
15 " " " "	1.262 "
20 " " " "	1.275 "
25 " " " "	1.287 "
30 " " " "	1.300 "
35 " " " "	1.312 "
40 " " " "	1.325 "

In order to find the loss in the brushes due to this drop, it is simply necessary to multiply the drop by the armature current flowing.

In the case under consideration the area of half the number of brushes is 27.6 square inches. The current density is therfore 33 amperes per square inch.

The equivalent drop is thus 1.25+.575 volt=1.825 volts, and the loss = 914 × 1.825 = 1670 watts.

The efficiency curve and the curves of input and output are shown in Fig. 27.

A NOTE ON CENTRAL STATION DEVELOPMENT*

By W. C. L. EGLIN

IN THE construction of the early central station, the installation of the electrical equipment occupied only a minor position. The general plan of the station was invariably arranged to best suit mechanical requirements, frequently at the expense of the electrical equipment. The engines and generators were usually on different floors and connected together with driving mechanisms consisting of an elaborate system of belting, shafting and friction clutches.

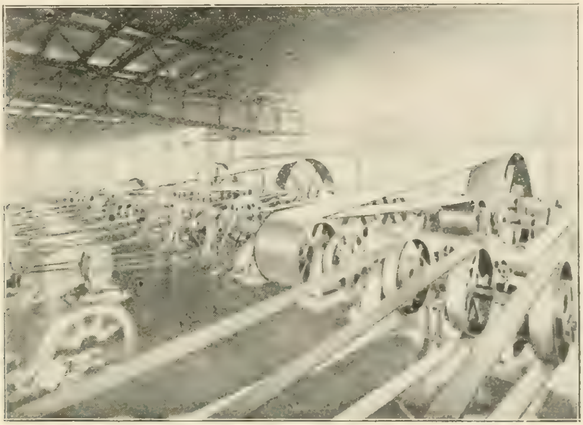


FIG. 1

The highest development of the central station from a mechanical standpoint was reached when the shafting and couplings became sufficiently complicated to enable any generator to be run by any engine, and any generator to be shut down independently of the others. Fig. 1 shows the dynamo room of such a station in Philadelphia as it appeared prior to its reconstruction by the Philadelphia Electric Company.

Experience has shown that the electric generator was not the weakest point in the system, and that its faults were much less than the complicated system of shafting and clutches which really formed the most unreliable part of the station, and caused most of the shutdowns, thus defeating the very object for which they were installed. Fig. 2 shows the reconstruction of this station and the elimination of all friction clutches and unnecessary shafting. From

---

*An Abstract of a Lecture before *The Electric Club.*

this view will be readily appreciated the reduction in the cost of installation and the reduced cost of operation and maintenance; and the very heavy friction loss which has been reduced by the removal of the intermediate shafts and the simplified construction. The decrease in the friction load after the change was about 200 hp. With the development of the engine type of generators, the driving of the generators has been reduced to its simplest form, materially simplifying the mechanical construction of the station.

The increased size of the units, and the higher voltage at which they are operated has necessitated the development of more elaborate electrical auxiliaries which require able engineering skill, both in their manufacture and installation; so that to-day the electrical equipment is the most important part of the station. Among the noticeable features in the development of the central station is the continuing increase in the capacity per unit of area. The Christian street station of the Philadelphia Electric Company has over ten times the kilowatt capacity per unit area of the station shown in Fig. 1, and the amount of space occupied by the controlling and distributing apparatus has increased from ten to twenty times over that of the older stations.

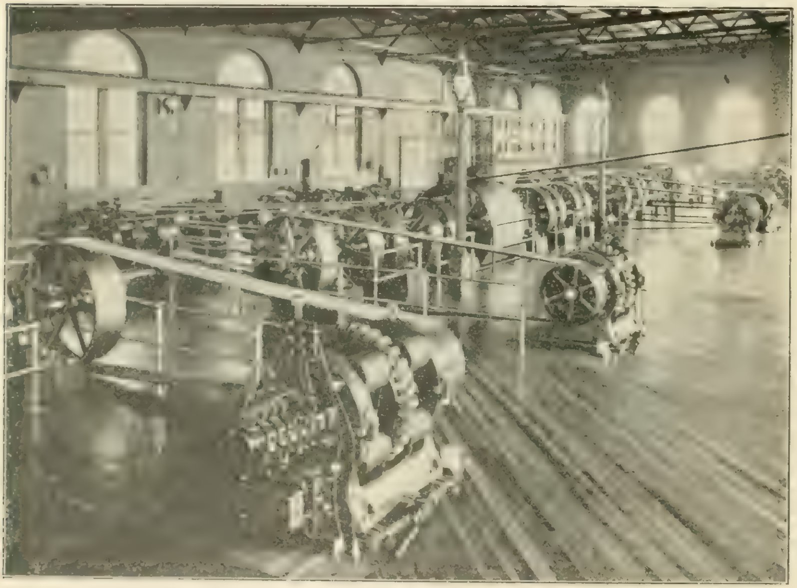


FIG. 2

SHOP EXPERIENCE

Items from the Note Book of the Apprentice

THE AIR-GAP OF TURBO-GENERATORS—The average observer, when first inspecting a Westinghouse turbo-generator, immediately asks *"Why is the air-gap so large?"*

The large air-gap is due to two elements of design, viz., the large output per pole as compared with slower-speed generators, and the relation between the section of the body of the poles and the area of the pole faces.

If we compare a moderate-speed, engine-type generator, as for example a Manhattan 5 000-kw generator and a 2-pole, 3 000-alternation 1 000-kw turbo-generator, we find that in the first case the output per pole is 125-kw and the air gap is 0.75", while in the second case the output per pole is 500-kw, or four times as great, and the air-gap is 2.5". Now, the difference in peripheral velocity is not very great in comparison with the revolutions per minute, so that the increase in output per pole requires a general increase in all the polar dimensions in the case of a turbo-generator, which is also shared by the air-gap.

If the air-gap in any generator is made very small, or just sufficient for good mechanical clearance, only a very small magnetizing force is necessary to give normal voltage in the armature with no current in the armature winding, but a small current in the armature will practically neutralize this weak magnetizing force, and the only way to maintain the intial voltage is to increase the field magnetizing force about in proportion to the increase in armature current, which means practically no inherent regulation.

If we desire to reduce the demagnetizing effect of the armture, we must increase the air-gap, but this in turn requires a greater field magnetizing force to maintain the original induction through the armature winding, so that by increasing the air-gap a double effect is obtained. The demagnetizing effect of the armature is reduced and the field magnetizing strength is necessarily increased, both of which contribute to better regulation. In turbo-generators the proportions are such that the armature ampere-turns are concentrated in a few poles, which gives a large armature reaction which requires a strong magnetizing field and a large air-gap.

In the design of Westinghouse turbo-generator fields the pole tips are necessarily larger than the body of the poles in order to support the field coils with safety against centrifugal forces. The area of pole face is therefore much larger than the body of a pole, which is a marked difference between the construction of turbo fields and a Westinghouse slow-speed generator field, in which the pole tip is the same size as the body of the pole. With the enlarged pole tip the magnetic induction is spread over a larger area and its density is reduced. It follows then from the simple relation that the magnetizing field strength is proportional to the length of air-gap and density of field, that with the enlarged pole tip the air-gap must be larger than with a pole having the same section throughout. This is the second factor in increasing the air-gap in turbo-generators.

Synchronizing Rheostats—In synchronizing a rotary converter by the use of an induction starting motor it is necessary that the motor have fewer poles than the converter, giving it a higher synchronous speed than the converter. The motor should then be so designed that its slip when delivering the torque necessary to drive the converter is just sufficient to reduce the speed to approximately the synchronous speed of the converter. Owing to the difficulty of exactly pre-determining the slip of an induction motor at a given load, and owing to changes in the frictional load of the converter itself, it is more or less difficult to adjust the motor to give the proper synchronizing speed. A means of changing the load upon the starting motor would give an easier and adjustable method of bringing the converter to synchronous speed. It is the purpose of the synchronizing rheostat to provide such a variable load.

The synchronizing rheostat consists of a cast-iron core of E section wound with a coil having several taps. The rheostat is connected directly across one phase of the converter so that the converter acts as a generator supplying the magnetizing losses of the rheostat and thus puts an additional load upon the starting motor, the principal portion of this load being the iron-loss in the rheostat core. By using different taps of the coil, the load due to the synchronizing rheostat may be varied, and in this way changes in the losses in the converter may be compensated for and the necessity of closely pre-determining the slip of the induction motor obviated.

When a synchronizing rheostat is used, the end rings of the starting motor are designed to give a maximum starting torque independent of the speed when running the converter at normal voltage. In synchronizing a converter, the starting motor is first thrown on and the converter allowed to reach synchronous or some higher speed. The synchronizing rheostat is then thrown directly across one phase of the converter, connection being made to that tap of the rheostat which gives a load just sufficient to bring the converter down to synchronous speed. The rheostat is designed to remain in circuit a few minutes without damage, giving ample time for synchronizing.

Large Commutator Construction—The bars are of hard-drawn copper, sawed slightly larger than the desired size when finished, or they may be drop forged, in which case they are stamped out to the proper size. Cast bars have been tried, but in the process of casting particles of sand become mixed with the copper which renders such bars useless.

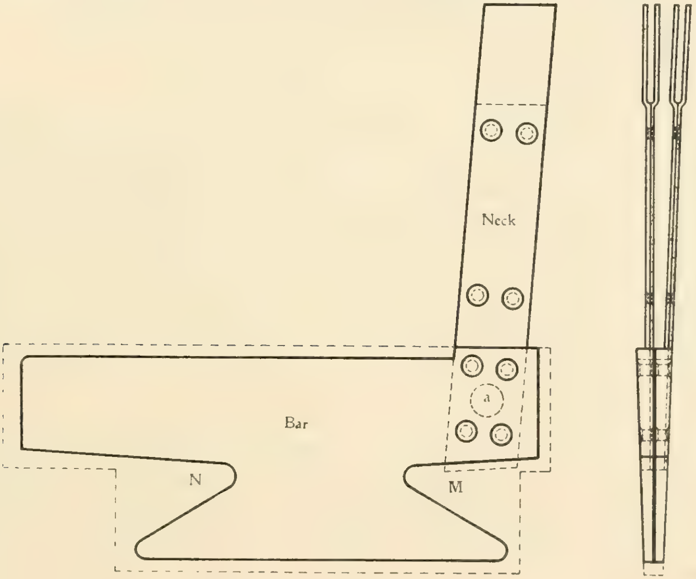


FIG. I—COMMUTATOR SEGMENT

The sides must be smooth and have the necessary taper for producing a commutator of a certain diameter. In Fig. 1 the bar and neck are shown joined together. The dotted lines represent the bar as it is sawed out and built into the commutator; the full lines represent the shape of the bar after the commutator has been machined. The bar has the well-known dove-tail projection universally used in commutator construction, to act in conjunction with clamping rings to hold the bars in place. The form of the neck here shown is employed on most of the medium and large-size machines and consists of two strips of copper, fastened together by two or four copper rivets according to the length of neck, and has a recess at the top for connecting the armature strap winding. The hole (a), ½″ in diameter, is punched in the neck and the rivet holes about (a) are drilled with the bar and neck held firmly together. After riveting the two with copper rivets the bar and neck are brazed together. After brazing the bars are finished off smooth at the joint and are ready to be built up in the commutator.

The mica insulation used in commutators may be divided into two classes:

(a) Bushings and V rings;
(b) Strips.

Bushing and V rings are made from white India mica which is best adapted for this work on account of its great flexibility and mechanical strength. The mica is obtained from the market in splittings, .001″ to .002″ in thickness, and about four square inches in area. This split mica is built up in plates 1/32″ thick, shellac being the bond used. These mica sheets are pressed between hot plates, are milled to exact thickness, then punched to proper size and finally molded. V rings are used in double layers, the joints being staggered.

Commutator strips are built up from amber Canadian mica, which, while somewhat inferior to India mica in mechanical strength, is softer and has equal insulating strength. India mica has been found too hard for this use, as in service the strips built of it wear more slowly than the copper and lift the brushes. North Carolina white mica, on account of its extreme hardness, is altogether unfitted for use in strips. The Canadian mica is built, in similar fashion to the India mica, into sheets. These are pressed between hot plates, milled, punched and inspected. Each individual piece is separately and carefully inspected in order to avoid strips of weak, non-homogeneous structure or of improper thickness.

The commutator is built up on a circular horizontal surface plate. An iron block is clamped vertically on top of the plate near the outer edge to act as a support for starting the row of bars. The copper segments are then set up side by side with the necks at the

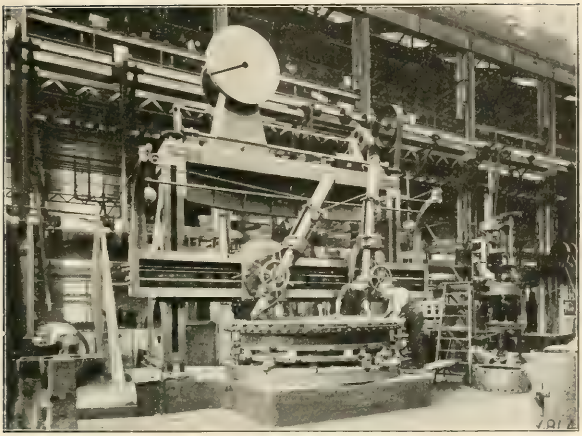


FIG. 2—MACHINING A LARGE COMMUTATOR

bottom and projecting outwardly. A heavy movable block is used to keep the segments in an upright position while building. When the required number of segments have been built up to form a complete circle the whole is loosely bound with rope or tape and the mica sheets placed between the segments. When the commutator bars are very heavy and thick, the mica sheets must be built up with the bars. When the copper and mica are all in place two binding rings are clamped about the bars to hold them together. Strips of fibre are used underneath the binding rings to protect the copper. When the rings are adjusted in place they are supported upon wooden blocks and the workman evens up the mica and bars by driving them against the fibre strips. The bars are set perpendicular by making the edges of the mica sheets parallel to a straight edge set perpendicular to the surface plate. When all the bars are properly set the screws in the clamping rings are tightened and the commutator is ready to be baked. In the baking process the commutator is placed upon the large iron block having a circular hole in the center. The inner surface is lined with sheet iron to prevent the flame from carbonizing the shellac in the mica strips and heat is supplied by gas flames. During the baking the set screws in the binding rings are occasionally tightened and any excess shellac forced out. When the shellac is thoroughly dried out the commutator is allowed to cool and then carried to a boring mill, where the inner surface is machined off. The mill is operated at a high rate of speed and air is used to blow the turnings from the work.

With large sizes a boring mill is often used having two tools operating on separate surfaces. Both ends are also machined off.

A test is then made for short-circuits between adjacent bars. If one should be found it may be due to particles of copper making a connection between bars on the outside of the mica, in which case the connecting copper is cut away with a sharp tool; or it may happen that the trouble is in the mica below the surface. To remedy this it is necessary to remove sections of the clamping rings over the defective point, loosen up two of the bars and replace the faulty mica with new. After a thorough test the inner surface is sandpapered smooth and shellaced and the commutator is then ready to be mounted upon the commutator spider. In medium size armatures, which are wound in the factory, the commutator spider is cast in one piece with the armature spider, and the outer surfaces of the commutator are not finished until the armature winding has been completed, when the complete armature is put in the lathe and the commutator turned off. In the largest armatures, which are wound in the power station during erection, the commutator spider is a separate casting. With this construction the commutator is mounted on the spider and the outer surfaces machined in a boring mill.

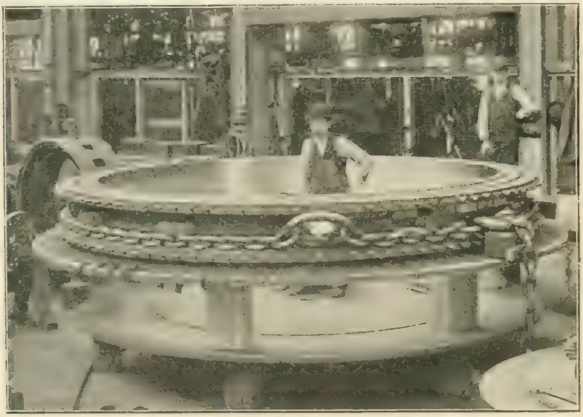


FIG. 3 A COMMUTATOR WITH THE INSIDE SURFACES FINISHED

Points in Transformer Coil Winding—In winding small transformer coils, having several turns of fine wire per layer, a mold is employed which has one end built in sections, such that the mold may be built up as the coil is wound. This arrangement allows the operator more freedom in starting the first few layers.

Sometimes it is desired to have the sheet insulation between the layers extend beyond the layers themselves. This condition is secured in a uniform manner by making the turns next the mold in each layer of cord and removing the cord after the coil is taken from the mold.

When a transformer coil is to be wound so as to have both terminals at the outside, a mold is sometimes used wide enough for the two turns side by side and supplied with a fiber dummy the width of one turn. The first half of the coil is wound up in the regular manner beside the dummy with one turn per layer. The dummy and coil are then removed from the mold, the coil reversed and then replaced in the mold and the second part wound up beside it. The connection at the inside may be a soldered one, or enough wire may be reversed at the beginning of the first part to wind up the second.

Many high-tension transformer coils with several turns per layer have all the layers wound in the same direction. The conductor, after completing the last turn on one layer, being carried over through an insulating sleeve to begin the first turn of the next. By this arrangement the potential between the extreme turns in any adjacent layers will be only half that which would obtain should the layers be wound back and forth, as is the usual custom in coil winding.

In the low-tension coils of large transformers two, four or some higher even number of conductors are often wound in parallel with one turn per layer and two conductors side by side. If the coil should be wound up in the mold with the conductors in multiple, always in the same position relative to one another, a greater e.m.f. would be induced in the half of the multiple winding nearer the high-tension coil than in the other. The result would be a local current, set up by the difference of these two e.m.f.'s, and flowing around the circuit formed by uniting the two conductors in multiple. To obviate this, the conductors in one of the turns, usually half way up in the coil, are made to exchange places, so that those which will be nearer the high-tension coil in the first half of the winding will be farther from it in the second half. The result is, the induced e.m.f. in one half will oppose an equal e.m.f. in the other, and no current will flow in the local circuit.

EDITORIAL COMMENT

Iron and Copper Losses of Transformers

The iron loss of a lighting transformer goes on day and night regardless of the amount of load supplied. The copper loss, however, occurs only when the transformer is loaded and, while it may be considerable at full load, it decreases very rapidly as the load falls off. As the transformer is seldom fully loaded, and in many cases supplies only a partial load for a few hours each day, the actual watts of iron loss far exceeds the actual watts of copper loss. This fact has been brought out strongly in recent years, and is appreciated generally by central station managers, who realize that this iron loss means increased coal bills. In fact, so strongly has this idea taken hold of some managers that "low iron loss" has become a hobby, and in their anxiety to force down this loss to the last watt, they overlook the consequent bulging in copper loss, heating and cost. The fallacy of this theory is pointed out clearly by Mr. Fortescue in another page of this issue. He shows that in the great majority of cases the copper loss is of far greater importance than the iron loss.

The basis for Mr. Fortescue's argument is:

1. For lighting service the copper loss in per cent equals (approx.) the regulation in per cent.
2. Where transformers not equally loaded are supplied from the same primary mains, constant secondary voltage cannot be maintained. The closer the regulation of the transformer the more nearly constant the secondary voltage.

If a transformer having 2 per cent. regulation be supplied from constant voltage primary mains, and if its normal no load secondary voltage is 100, then its full load secondary voltage will be 98. But this drop of 2 per cent. in secondary voltage means 2 per cent. less current supplied to the lamps, and since the wattmeter reading is the product of life current (2 per cent. less than normal) by the voltage (2 per cent. less than normal) it will evidently be 4 per cent. less than normal, i. e., 4 per cent. less than though the secondary had been maintained constant at 100 volts.

Every watt-hour lost by a reduction in the meter reading must be charged at the selling price of energy, while a watt-hour in iron loss is measured only in the cost of coal which is required to produce it. But the selling price of energy may be from 10 to 100 times the cost of the producing coal, so that a reduction of one watt hour in the meter reading may outweigh a saving of 10 to 100 watt-hours in iron loss.

To sum up: The copper loss determines the regulation. The regulation directly affect the wattmeter reading. And a transformer having a relatively high iron loss but low copper loss, is usually far more economical to operate than one having a relatively low iron loss but high copper loss.

It is true that the increased revenue from the transformer having the lower copper loss is obtained from the customer, but his illumination is increased more than his bill, while the cost of lamp renewals is reduced.

It is also pointed out by Mr. Fortescue that for equal full-load efficiencies, the transformer having equal iron and copper losses is cheaper to manufacture than one in which the iron loss is reduced, even though the copper loss is correspondingly increased. Thus, not only is the low iron loss transformer more extensive to operate, but its first cost is higher than a transformer having the same full load efficiency, but equal iron and copper losses.

In water power plants where the cost of generating the transformer iron loss is practically nil the arguments used by Mr. Fortescue in favor of low copper loss apply with even greater force than in steam-driven plants.

J. S. Peck.

THE OPPORTUNITY OF THE ENGINEER

The official estimates of the Government make the present population of the United States 80,000,000.

Reasoning from the past it seems probable that 25 years from now our population will be 125,000,000.

That is, by the time that the young engineers now starting their life-work have reached a ripe and active middle age the population of the United States will be as great as the present population of the United Kingdom, the German Empire and two-thirds of France, added together.

It will be a homogeneous population, of high average education, and averaging higher in courage, enterprise and self-reliance than the people of any other great country, for reasons which we need not now go into.

That population will be planted in a temperate climate, in a country of unequalled natural resources, intersected by great natural waterways, covered with a net-work of railroads, and with vast coast lines on the two great oceans.

The wealth, the power, the physical and intellectual influence of such a nation may be guessed at; they cannot be measured.

Such is the inheritance of the American youth who stand today in the gateway of life.

To the young engineer all this has an especial meaning.

Heretofore we have been relatively an agricultural people.

Soon we shall be relatively a manufacturing people.

Doubtless we shall long continue to be the greatest food producing nation; but we shall come to be also the greatest manufacturing nation.

The opportunities we offered to courage and enterprise have been the greatest the world ever saw; henceforward the great opportunities will be for courage and enterprise plus highly trained intelligence.

That means that the great prizes of the next quarter of a century will be for the engineer.

But if he will grasp them he must be not only an engineer; he must be a man.

—*H. G. Prout.*

THE GAUGING OF MATERIALS

A new method for the gauging of materials less than 0.5″ in thickness or diameter became effective in the works of the Westinghouse Electric & Manufacturing Company on April 1st, 1904. This method is quite fully described in the pamphlet recently issued by the company, bearing the title "The Gauging of Material." The essential difference between the old and the new method of gauging being the substitution of the decimal divisions of the inch for the numerous meaningless numbered gauges heretofore used.

Some of the reasons leading up to the adoption of this new method deserve brief notice. A great amount of confusion existed in the works, due to the fact that ten different wire and sheet metal gauges were used, each gauge having a set of arbitrary numbers to represent given sizes of material. The different gauge numbers were alike only in rare instances, and unless a particular gauge was specified the material ordered might prove larger or smaller than desired, because a different gauge was used by the manufacturer than the one intended by the purchaser. Sheets of different metals were made to different gauge systems, and the workman (unless supplied with more than one gauge) would call for material by the gauge used by him. Materials bought by one gauge system were frequently carried in stock by another gauge system. As an instance, we carried two sizes of banding wire in stock—one 0.0453″ diameter the other 0.038″ diameter, but both were known to the trade as No. 17 banding wire; the former being the correct decimal size for the No. 17 Brown & Sharpe Gauge to which phosphor bronze wire is drawn, the latter being the correct decimals size for the No. 17 Music Wire Gauge. The difference between the No. 17 size in these two gauges being 0.0073″.

The Sub-Committee, to whom the question of the gauging of materials was referred by the Materials Committee, at their early meetings strongly favored the adoption of the Master Mechanics Standard Decimal Gauge, in which size is known and expressed by a decimal part of the inch, as 0.002″—0.150″—0.250″, etc. After due consideration of the various points involved in such a radical change, the following recommendations were adopted:

(1) "That all gauge numbers be dropped and that decimal sizes only be used.

(2) "That the extreme refinements, as shown by the fourth and fifth significant figures given in some of the tables of gauges, be dropped.

(3) "That materials now purchased by different gauges be purchased of the same dimensions as heretofore, but that the gauge numbers be omitted.

(4) "The preceding recommendation will require that all gauging in the factory be done by the micrometer instead of wire gauges.

(5) "The Purchasing Department specifications should be made out showing limits of variation for each kind of material, these limits to be sufficiently wide so that standard materials made in accordance with the gauges now in use will fulfill our specifications.

(6) "The various systems of keeping stock by numbers should be changed to give certain dimensions.

(7) "On our standard sheets for gauge dimensions some indication should be given for those sizes which are most commonly used or kept in stock, with recommendation to adhere to these as closely as possible."

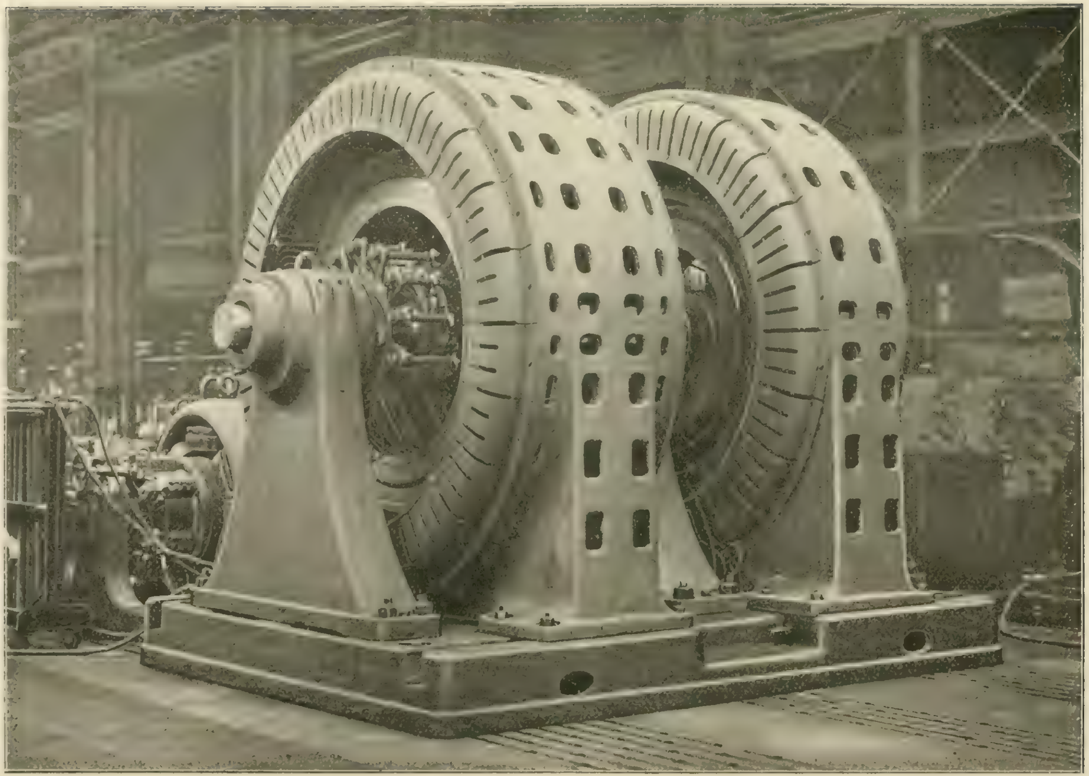
Among the advantages arising from the adoption of this new system of gauging are:

(a) All materials will be known by a number which is representative of the dimensions of the material.

(b) As all materials will be gauged in thousandths of an inch, there can be no confusion due to different gauge systems, and no matter what gauge system the manufacturer of the material uses, we will know it by its dimensions.

(c) By adopting the dimensions of the present standard gauges we do not cause any confusion with the manufacturers by ordering materials of sizes different from their standards.

C. C. Tyler.



1 000 KW FREQUENCY CHANGER

Used by the New York Edison Company for converting 25 cycle current to a periodicity of 60 cycles. It consists of a 1 400 hp., three-phase, 25 cycle, 6 300 volt Type F Induction Motor, direct connected to a 1 000 kw, two-phase, 60 cycle, 3 000 volt Rotating Field Generator.

THE
ELECTRIC CLUB JOURNAL

VOL. I JULY, 1904 NO. 6

THE MODERN TELEPHONE*

By S. P. GRACE
Engineer of the Central District and Printing Telegraph Company

THE transmission of articulate speech beyond the ordinary range of the human voice has been the goal towards which scientists have labored for centuries. To-day, observing on every hand how readily speech is transmitted from one section of the country to another, we are inclined not to realize the great amount of mental and manual effort that has been necessary in order that our speech be extended over hundreds and even thousands of miles. To understand clearly the electrical and mechanical principles made use of in the modern telephone system, it is first necessary to acquaint ourselves with the physical laws underlying speech. It is well known that sound has its origin in the vibration of the molecules of the air which alternately give rise to atmospheric condensations and rare-

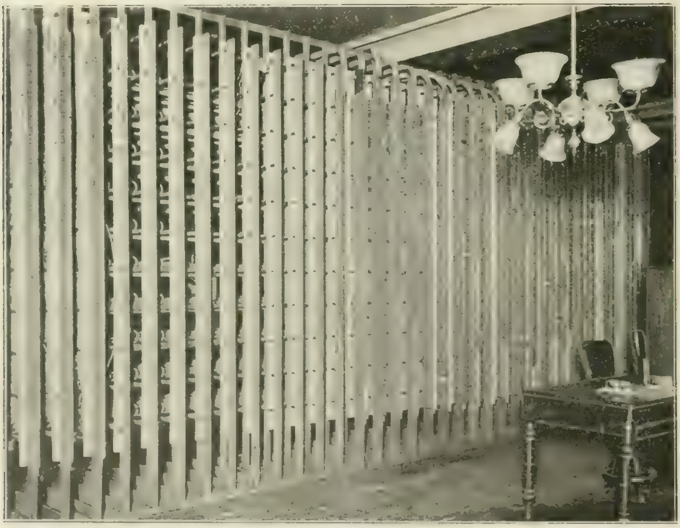
CHIEF OPERATOR'S TABLE

---

*A Lecture delivered before THE ELECTRIC CLUB.

factions; *i. e.*, changes of pressure. The condensations and rarefactions of the air reaching the drum of the ear throw it into vibration. The vibration of the ear drum excites the acoustic nerves and in some way, not wholly comprehended, convey to the brain the impression of sound. The simplest form of sound vibration is that produced by the ordinary tuning fork, which gives out a round, full tone of fundamental character. The most complex sounds in nature are those of the human voice, which by slight changes of inflexion convey an entirely different meaning with the same words, though apparently of the same loudness and the same pitch.

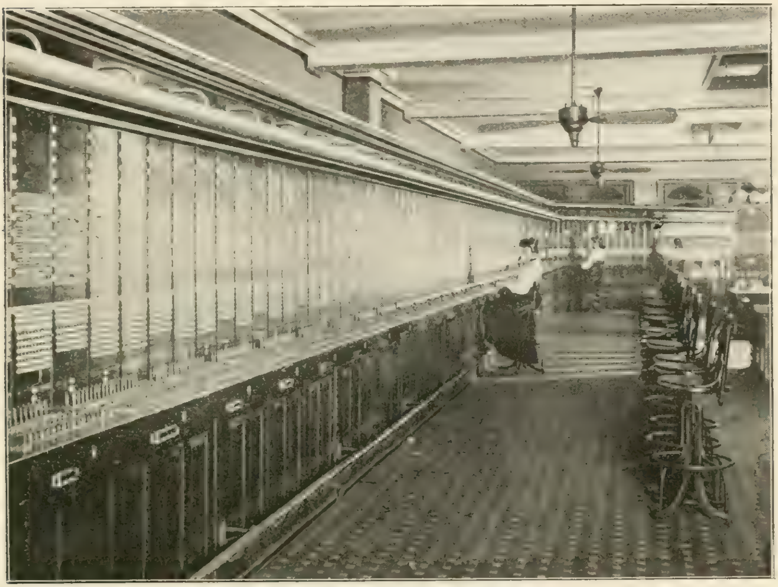
Sound may be divided into three general characteristics, loudness, pitch and quality. One sound may be louder than another due to a greater amplitude of vibration of the body producing the sound, which therefore produces greater condensations and rarefactions in the atmosphere. Again, two sounds may be of the same loudness, but of a different pitch, or technically speaking, a different number of vibrations per second. As an example of pitch, suppose we strike the key C in adjacent octaves on a piano. The number of vibrations per second of C in the higher octave is just twice that of C in the lower octave.



FRONT OF MAIN DISTRIBUTING FRAME

The last characteristic of sound, that of quality, is, perhaps, the most important. Very few sounds in nature are fundamentals.

Practically all musical instruments and the human voice in particular give out sounds composed of partial tones, or overtones, in combination with the fundamental tone. As a familiar example consider a vibrating string stretched between two points. By plucking the string in the center it is possible to make the string vibrate as a whole and thus give a fundamental tone of a pitch depending upon how tightly the string was stretched. The tighter the string is stretched the greater will be the number of vibrations per second, and the higher the key of the note produced. Should the string be plucked away from the center it will be thrown into sectional vibrations. If the string vibrates in two parts we would then have the fundamental note combined with the second overtone; if in four parts, with the fourth overtone, and so on.



LOCAL SWITCHBOARD—FRONT VIEW

In general then the quality of a sound depends upon the number, the intensity and the position of the overtones. It is this arrangement of the overtones which makes the same note on a violin different from the same note on a piano, a guitar, or a mandolin. The overtones are also responsible for the differences between human voices. Because of the variety and number of the overtones the sounds produced by the vocal cords are of a very complex character, and the resulting air waves have vibration rates ranging all the way from 200 to 5 000 per second. To the great German scientist, Von Helmholtz, is due our knowledge of the laws governing the quality of sound.

To transmit the sound waves of the human voice electrically to a distance is at once seen to present many serious problems. Obviously an electrical current must be capable of changing and reversing many hundreds and even thousands of times per second. It was not until 1876 that Alexander Graham Bell succeeded in making one diaphragm perform exactly the same evolutions as a diaphragm located many feet away, and which was thrown into vibration by means of a human voice spoken against it. Bell clearly saw that if speech was to be transmitted electrically it must be done by a current which was undulatory in character, and that the circuit must never be electrically broken. The telephone of Bell was delightfully simple; it consisted merely of a magnet provided with an extension iron pole piece, about which piece was wrapped a few turns of insulated wire. The placing of a thin iron diaphragm in front of the pole piece and separated from it by a small air-gap completed his invention..

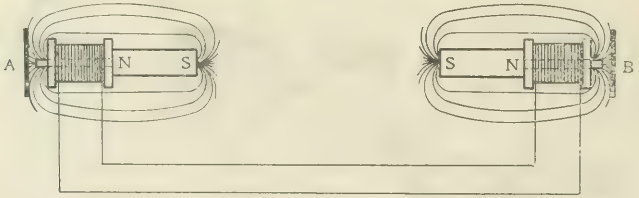
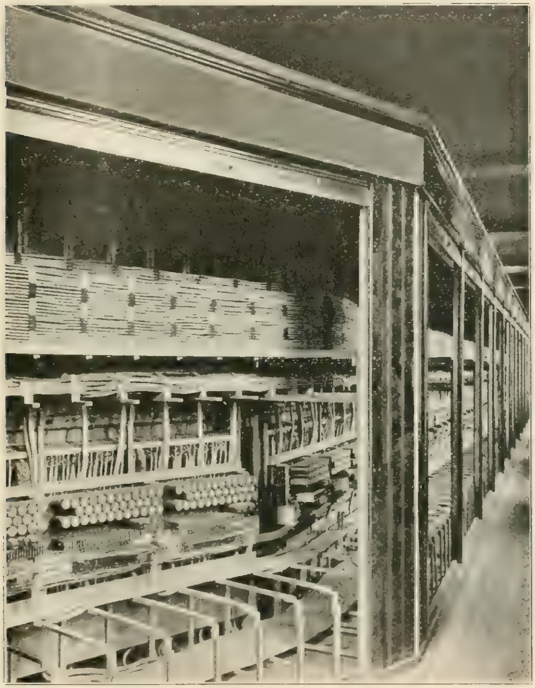


FIG. 1

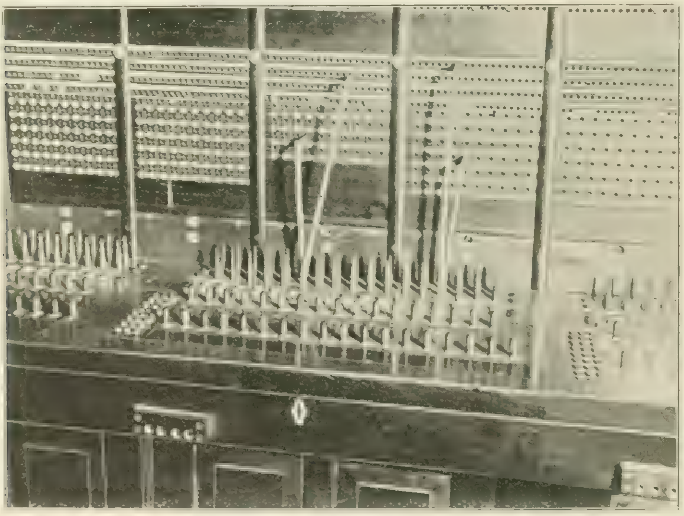
Bell's telephone will act either as a transmitter or a receiver. I have shown in Fig. 1, a skeleton diagram of Bell's original telephone, and, in fact, the telephone receiver exists to-day practically as designed by Bell 25 years ago. If the diaphragm of *A* be spoken against it will be thrown into vibration in nearly exact accordance with the condensations and rarefactions of the air waves striking it. The diaphragm being made of iron will therefore, by its change of distance from the pole piece, permit a greater or lesser flow of magnetic force through the coil of wire on the pole piece. Because by changing the field of magnetic force through a closed coil there are set up in it electrical currents which are directly proportional to the rate of change of magnetic force. Suppose the wires from *A* are connected into a similar instrument at *B*. The varying current from *A* traversing the coil at instrument *B* will increase or decrease the magnetic field of instrument *B* and will therefore vary the pull upon its diaphragm. Obviously diaphragm *B* will be thrown into vibration and its vibrations will be practically identical with the vibrations of diaphragm *A*. Since the vibrations of diaphragm *A* correspond with the sound waves produced by the vocal cords of the person speaking at *A*, similar sound waves will be set up by the diaphragm at *B*. These, reaching the ear of the observer at *B*, will actuate his ear drum and the acoustic nerves will convey to his brain the impression of the sound waves as originally spoken at *A*.



LOCAL SWITCHBOARD—REAR VIEW

The original Bell instrument, though transmitting and receiving speech with remarkable clearness, was still inadequate for use as a transmitter because of the faintness of the transmission. Bell's instrument as a receiver is one of the most remarkably delicate instruments known to electrical science. This may be fully realized from the statement that one two-millionth of an ampere will produce an audible sound in a Bell telephone receiver.

It was only a short time until the genius of Berliner and Edison evolved a transmitter which would act, so to speak, as a valve on a source of electrical energy. When Bell's instrument is used as a transmitter the energy of the sound waves conveyed to the diaphragm produces the electrical energy in the coil around the pole piece. From the well known law of the conservation of energy it is obvious that the amount of electrical energy cannot exceed the mechanical energy of the vibrating diaphragm. The Berliner and Edison transmitter depends upon the variable resistance of two bodies placed loosely in contact, when subjected to changes of pressure. The most successful forms of transmitters make use of the variable resistances between two carbon electrodes separated by means of carbon granules. It has been found that if one of these electrodes be connected to a diaphragm which is spoken against, the resistance of the carbon will vary in accordance with the pressure upon the electrodes and therefore with the condensations and rarefactions in the air waves striking the diaphragm. If there is a current of electricity from a battery flowing through this contact it is clear that the current will be varied in exact accordance with the sound waves striking the diaphragm.



KEYBOARD IN FRONT OF SWITCHBOARD

In Fig. 2 is shown two transmitters and two receivers connected serially in a circuit containing a battery. When either transmitter is spoken into, a variable current is produced in the circuit which will produce a varying magnetic field in both receivers and force their diaphragms into vibration. These receiver diaphragms will perform the same evolutions as the transmitter diaphragm which is spoken against and will therefore reproduce speech. That the diaphragms of both the transmitters and receivers are capable of taking up the minute overtones of the human voice is truly remarkable. That this is so is conclusively proven by the fact that

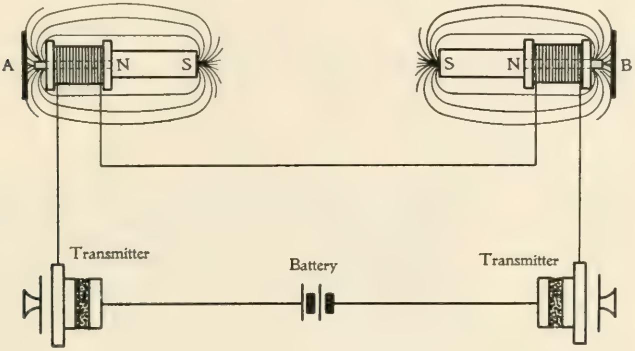


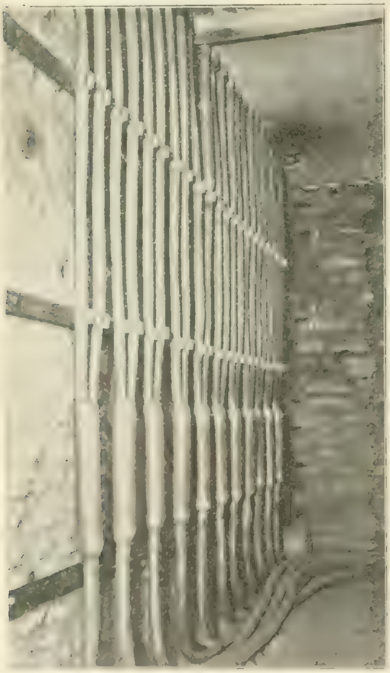
FIG. 2

familiar voices are at once recognized in the telephone, which would not be the case if the number, intensity and position of the overtones were not practically the same at the receiving end of the line as at the transmitting end. The overtones of some letters are very numerous and complicated, and are very difficult to transmit electrically. This is particularly true of the letter S and a number of other consonants. Strictly speaking, the received sounds have not exactly the same quality as the transmitted sounds, but they are sufficiently clear for practical purposes.

It has been very often asked why a permanent magnet is used in a telephone receiver. One reason is that if no permanent magnet be used the received sounds will be an octave above the sounds at the transmitting end. It is also because the amount of movement of the diaphragm for a small change of current is within practical limits proportional to the strength of the permanent magnetic field. Suppose in a telephone receiver that H equals the initial permanent magnetic force. Then the force acting upon the diaphragm is proportional to the square of the magnetization or H^2. If the magnetization increases a small amount h due to a slight change of current in the magnetizing coil, the pull on the diaphragm will be $(H+h)^2$. The difference or change in pull will therefore be $(H+h)^2-H^2=2Hh+h^2$. From this formula it is evident that the pull on the diaphragm will increase without limit as H or the initial magnetization is increased. The practical limit, however, is the degree of magnetization at which the iron in the diaphragm becomes saturated.

The secret of a good transmitter lies in the arrangement and treatment of the carbon electrodes and carbon granules. In designing the solid back transmitter used by the Bell Telephone Companies many years of careful laboratory experimentation were required before a thoroughly efficient and durable grade of carbon was produced. For transmitter use I may say that a carbon of almost glass hardness and extreme durability is required.

Electric light and power engineers very rarely have to deal with frequencies exceeding 125 cycles per second. To the telephone engineer who deals in frequencies of 300 to 5 000 per second, 125 cycles appear ridiculously small. While the telephone currents are not of large magnitude it is readily conceived that because of their high frequency the distorting and attenuating effects of self-induction and capacity are very marked. It is imperative, therefore, on all long aerial lines and cable lines that the distributed capacity be a minimum. Great care must be exercised not to place impedance in improper places in a telephone circuit, for if this is done serious choking effects may be produced on the telephone current, or if the line is so long that the transmission assumes a wave form there may be serious reflections of current from improperly placed impedance coils. Telephone engineers dealt with capacity and impedance long before their importance was realized by electric light and power engineers and were obliged to develop apparatus and lines which would work under these severe conditions of high frequency. The most recent work on this subject has been done by Dr. Pupin, who has shown how largely to counteract the effects of distributed capacity by means of distributed self-inductance. In

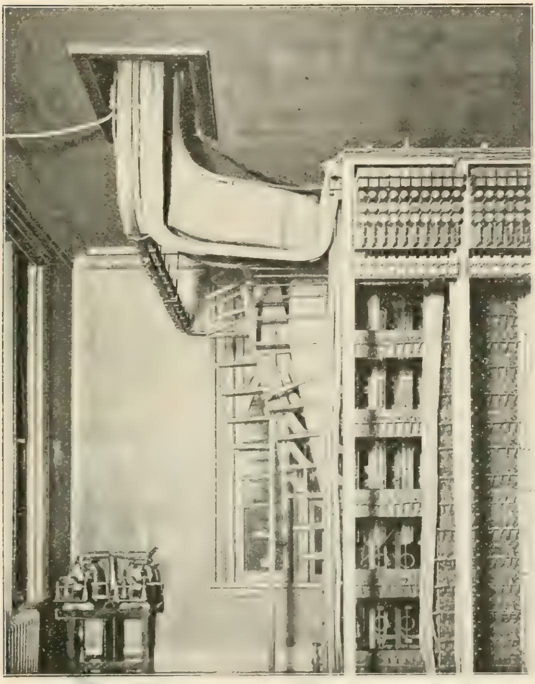


CABLE VAULT

Pupin's system impedance coils, known as load coils, are placed at recurrent intervals in the line depending upon the wave length.

The telephone receiver and transmitter which I have described would be of little value in the business world if some means were not provided so that conversations could be carried on between any two instruments in a system containing thousands of telephones. The invention of the telephone receiver and transmitter started the march of invention of central office switching devices.

Until the last decade the systems of switching were, to a great extent, crude, and were rapidly proving themselves incapable of handling the vast volume of traffic which they were called upon to carry. About seven years ago the old magneto-type switchboards were abandoned and were replaced by the common battery systems of to-day. The three great advantages of the common battery system may be summed up as: First, improved quality of service to the public; second, increased speed of operation; third, reduction of maintenance.



CABLE RUN BETWEEN MAIN BOARD AND INTERMEDIATE DISTRIBUTING FRAME

Of the different common battery systems, the repeating coil system is the one most generally used. This is shown diagrammatically in Fig. 3. One large storage battery is used as a source of current for all of the lines. Two telephone lines are connected by two flexible cords, in which are placed repeating coils which are simply transformers having the same number of turns in primary and secondary coils. The two lines are connected to the main battery, as shown. It is apparent that any change of current in either telephone circuit, caused by a variation of the transmitter resistance will, through the action of the transformer, be reproduced in the other or receiving telephone circuit. Any number of lines, with their repeating coils, may be connected to the one battery with no danger of "cross-talk" from one line to another. "Cross-talk" would be caused if the variable current in one repeating coil caused a change in the current in another coil, but on account of the low resistance of the battery this is not possible.

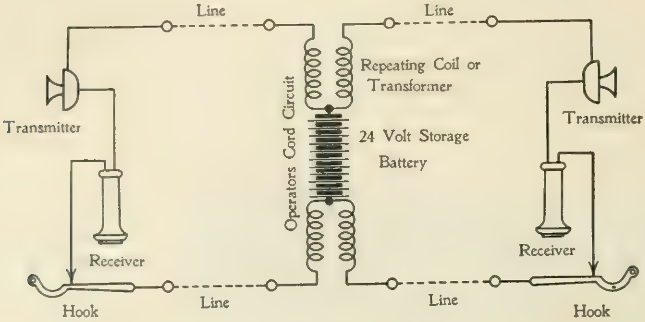
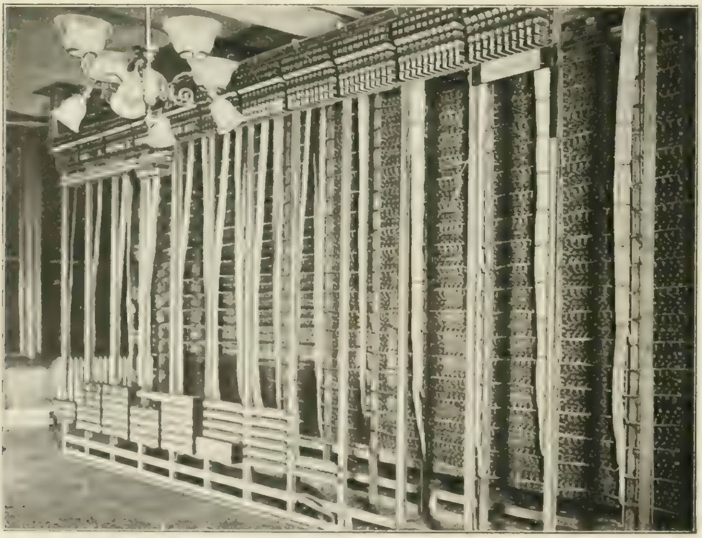


FIG. 3



RELAY RACK

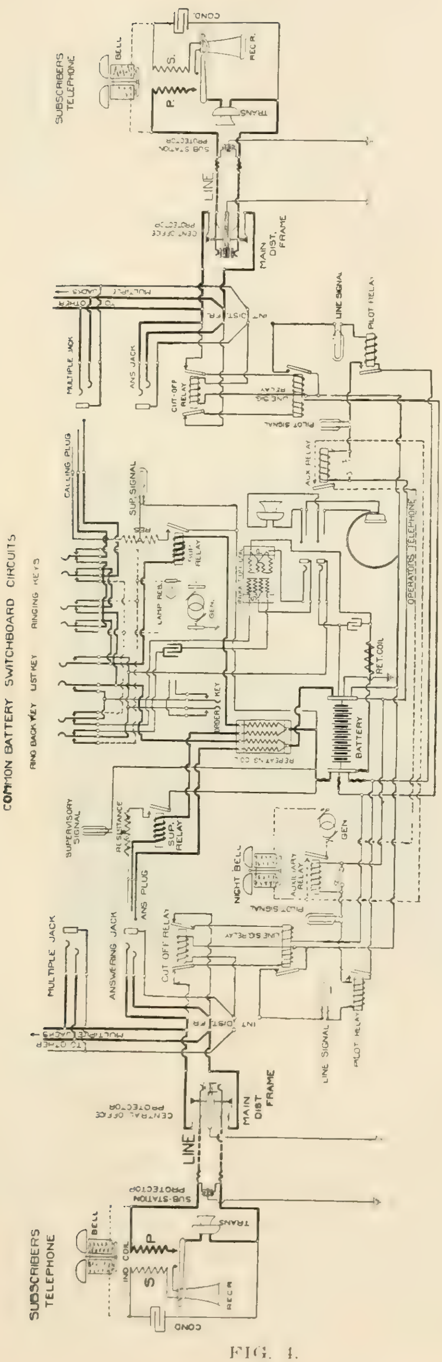
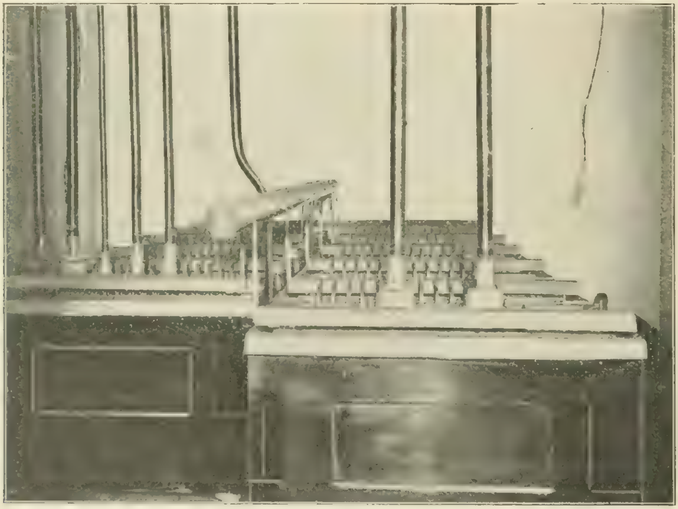


FIG. 4.

Fig. 4 represents the complete connections between two subscribers through a repeating-coil, common battery switchboard. At the left of the diagram is shown the connections of a subscriber's telephone. The apparatus in the telephone consists of a transmitter, a receiver, an induction coil, a condenser, a polarized bell and a hook switch. The functions of the transmitter and receiver have already been explained. The induction coil, which is nothing more than a small transformer, is used so that the receiver will be out of the line circuit, which includes the main battery. It has been found that direct current through the receiver is liable to demagnetize the permanent magnet and to injure the diaphragm. The condenser is placed in the instrument in order that the two sides of the line circuit may be kept open to the direct current which tries to flow from the central office main battery, thus preventing the operation of the line signal relay at central. The operator can ring the polarized bell at the subscriber's telephone through the two microfarad condenser, since for ringing purposes single-phase alternating current is used which passes readily through the condenser.

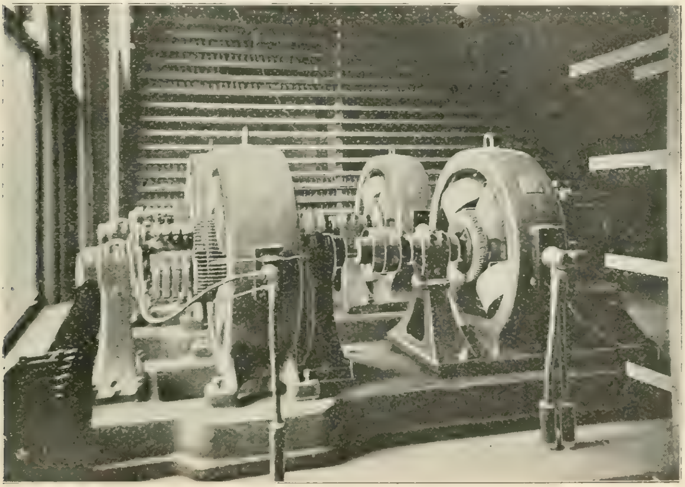
The underground and outside wire plant of a large telephone exchange is very extensive and great skill is required in the proper designing and the construction of the underground conduits, pole lines and aerial cables so that a high insulation may be maintained on all the lines and so that the wire plant will be valuable for use at any point where service is demanded. It is clear that no matter how good our instruments or our switchboards may be, without good line construction poor service will result. The best practice of to-day recommends that as much of the wire plant as is economical be placed underground and that where the distribution is not heavy enough to warrant underground conduit, that the wires be run in aerial cables on short heavy pole lines. These cables are made up of twisted pair wires insulated with spiral wrappings of paper and the whole enclosed in a continuous lead sheath. As many as 600 pairs of wires are sometimes placed in a single cable. The reason for using a paper insulated and lead covered cable is, first, because of its low cost, and, second, that with a paper insulation we obtain a very low mutual static capacity of each pair of wires. This low capacity is necessary in order not to seriously attenuate or distort the high-frequency telephone currents traversing over the circuit.



STORAGE BATTERY

On entering the central office the cables are ended in what is called the main distributing frame. From this, the pairs of wires pass through arresters or protectors to the intermediate frame and then to the switchboard. Each telephone line appears on the switchboard in a switch which is known as an answering jack. In addition, the line appears in what is known as the multiple jacks in every third position of the entire switchboard. The purpose of the multiple jacks is to enable any operator to plug in any line. This completes the connection of a subscriber's line to the switchboard. The remaining connections shown in Fig. 4 are for the connecting plugs containing the repeating coils, the operator's telephone and the signals.

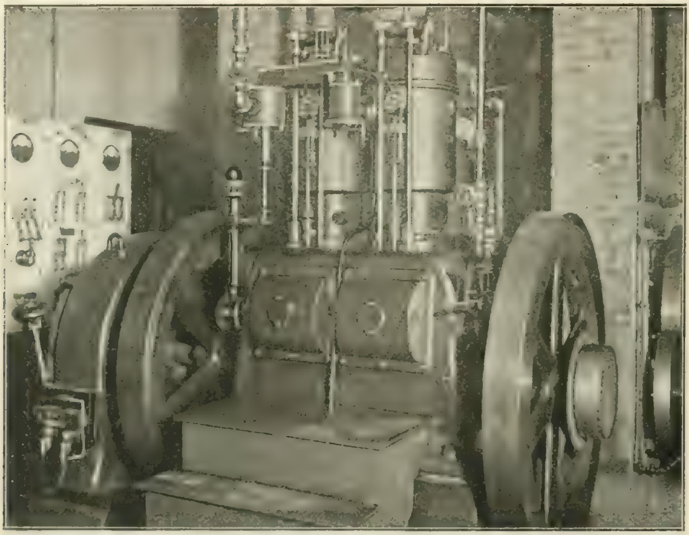
It will be seen that in the switchboard three wires and three jack and plug contacts are used for each line. Two of these wires are for the talking circuit the third being a signaling or controlling circuit for the operation of the various relays, signal lamps, etc., which are necessary for a proper supervision of the connection.



BATTERY CHARGING GENERATING PLANT

When the subscriber removes his receiver from the hook, the rising of the hook will close the contacts of the switch and close the line at the subscriber's station through the transmitter, the primary of the induction coil, and the hook switch contacts. The line being now closed will permit of current flowing through it from the main battery, and since the line signal relay is inserted serially in this circuit at the central office its armature will be attracted, which, closing a secondary circuit, will cause the lighting of the line lamp in the face of the switchboard adjacent to the answering jack of the subscriber who has called. The lighting of the line lamp is practically simultaneous with the removing of the receiver from the hook.

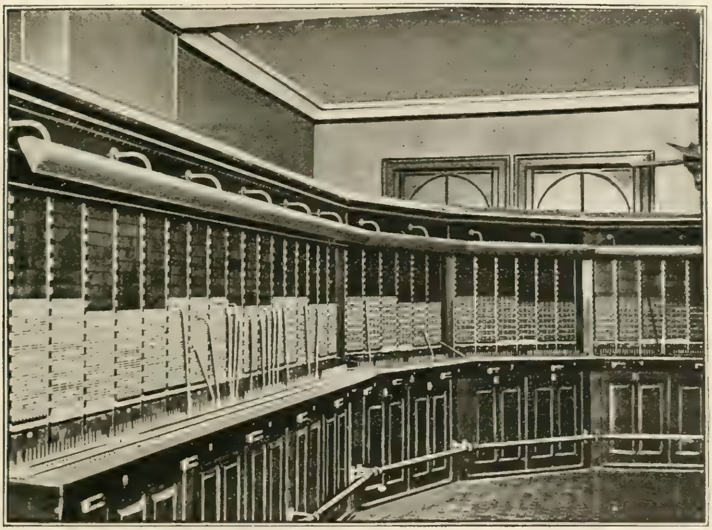
As previously stated the operator is provided with a number of pairs of double-ended plugs and cords which are so wired as to permit of the connection of two subscribers' lines. Upon seeing the line lamp light the operator will pick up a plug connected to one of her answering cords and insert it into the answering jack associated with the lighted line lamp. The inserting of the plug in the answering jack causes a flow of current in the controlling, or third wire circuit. It will be noticed that this current in the third wire flows through the cut-off relays, thus causing its armature to attract and open the circuit through the line lamp. This causes the extinguishment of the line lamp automatically. As the subscriber has his receiver off the hook the line is closed at the telephone, and as soon as the plug is fully inserted the line current, which the instant before was broken by the cut-off relay, is re-established through one-half of the repeating coil and the cord circuit. The current flowing in the main line will cause the operation of the 10-ohm supervisory relay which is placed in series with one



GAS ENGINES

side of the cord circuit. This relay being operated will connect the 40-ohm shunt around the supervisory lamp which, therefore, will not receive sufficient current to be illuminated. The operator will now depress her listening key which will connect her telephone set in parallel with the cord circuit which is connected to the subscriber's line. She will now speak into her transmitter and obtain from the subscriber the number wanted. The operator's set is practically the same as an ordinary telephone, but arranged with switching devices so that it may be connected to the various cord circuits.

Upon receiving the number wanted the operator will take the calling plug of the same pair of cords and reaching to the multiple jack of that number will touch the sleeve of the jack with the tip of the plug. In Fig. 4 the called subscriber's line is represented at the right of the diagram. If the subscriber's line wanted is plugged at some other part of the board the potential of the sleeves of all the multiple jacks of that line will be raised above the earth and under this condition if the sleeves of any of these multiple jacks are touched by the tip of a plug there will be a rush of current through the cord circuit which will cause a click in the operator's ear and thus inform her that the line is "busy." If the line wanted is not busy, which would be indicated by silence when the tip of the plug



TRUNK SWITCHBOARD—FRONT VIEW

is touched to the sleeve of the jack, the operator will fully insert the plug and depress one of her ringing keys connected to the cord. This will send a single-phase alternating current over the line of the called subscriber through the condenser and bell located in his telephone. The ringing of the bell will summon the called subscriber to his telephone.

The insertion of the calling plug has operated the cut-off relay and will prevent the called subscriber from flashing his line lamp when he answers the call. However, until the called subscriber answers, the supervisory relay connected with the calling plug will not be operated and, therefore, no shunt will be around the supervisory lamp. The supervisory lamp will thus be illuminated and will clearly indicate to the operator that the called subscriber has not answered. She will, therefore, keep on ringing until he answers or finally send back a "don't answer" report to the calling subscriber. Should he answer, current will flow through both sides of the line from the right-hand half of the repeating coil and will operate the supervisory relay which will shunt the supervisory lamp and cause it to be extinguished. The connection now being completely established the two subscribers will converse with each other on the principles already described. When the conversation is finished and both subscribers hang up their receivers both lines will be opened at the hook contacts and the supervisory relays will release. This will remove the shunt from around the supervisory lamps and cause them to be illuminated. The lighting of the supervisory lamps connected with the cord circuits indicates to the operator that the conversation is finished. She will then remove the plugs from both the answering jack and the multiple jack and all circuits will return to normal and all lamps will be extinguished.

The circuits above described show the connections which take place for local connections between two subscribers connected with the same office. In a modern telephone system in a large city this is only one of the many hundreds of circuit combinations which must be used. There must be provided suitable trunks and signals between relay offices for local connections and for toll connections, trunks between long distance boards and local boards, order wire circuits and ringing circuits to private branch exchanges, etc. So many are the circuit combinations that a complete description of them is practically impossible and would be out of place in a paper of this character.

TESTING OF SHEET STEEL*

By C. E. SKINNER

AT THE present time the rate of consumption of sheet steel in the manufacture of electrical apparatus in the United States alone is probably not less than one hundred million pounds per year. Assuming that twenty per cent. of this material is subjected to the conditions under which the so-called iron-loss occurs and that this loss is one and one-half watts per pound, we find we have a total loss of 30 000 kilowatts (40 000 horse-power), or an amount of power approaching the output of the largest single electrical power station in existence. At the rate of twenty-five dollars per horse-power per year this represents a money value of one million dollars. This loss manifests itself as heat in the apparatus and, therefore, serves no useful purposes, but forms one of the limitations to the output of the apparatus.

The losses referred to are the hysteresis and eddy-current losses, more commonly combined under the general term "iron-loss." This loss occurs in all magnetic material which is subjected to alternating magnetic stresses, the amount of the loss in any given material depending upon a number of conditions which will be referred to later.

In general the following must be taken into consideration in connection with the testing of sheet steel for electrical purposes:

(1) The losses in different sheet steels vary greatly with the chemical composition and with the physical condition due to the heat treatment and the mechanical working which the steel has received.

(2) In most sheet steel the losses may be reduced by annealing to a relatively small value.

(3) Nearly all steels, when the losses are reduced to a low value by annealing, are subject in a greater or less degree to aging, or increase in loss, due to the influence of comparatively low temperatures.

(4) The permeability of all steels which may be rolled commercially differs by a comparatively small amount, no matter what their condition with respect to annealing.

---

*A paper read before the American Society for Testing Materials, Atlantic City, N. J., June 18th.

(5) In all commercial sheet steels the physical characteristics are well above the service requirements.

The commercial testing of sheet steel for electrical purposes therefore resolves itself into:

(a) Chemical tests to determine the composition of the steel.

(b) Electrical tests to determine the losses in the steel after punching, before and after annealing.

(c) Electrical tests to determine whether aging, or increase in the losses, occurs when the steel is subjected to moderate temperatures.

(d) Tests for permeability.

(a) CHEMICAL TESTS.

Sheet steel used for electrical purposes is always a very mild steel, the carbon rarely being above 0.15 per cent., the phosphorus, sulphur, silicon and manganese also usually being kept quite low. The composition may vary over comparatively wide limits and the steel still fulfill the necessary conditions as to quality. One or two complete analyses from each heat and occasional check analyses from the sheet before and after annealing are usually sufficient for the purpose.

(b) LOSS TESTS.

By far the most important tests are those to determine the hysteresis and eddy-current-losses, either separately or combined, the amount of these losses showing the electrical quality of the steel.

Hysteresis-Loss—Hysteresis-loss may be defined as the work done in reversing the magnetism in the steel, and it may be considered as the molecular friction due to the reversal of the magnetism, this friction manifesting itself as heat. The amount of hysteresis in a given steel varies with the composition, with the hardness, with the maximum induction at which the steel is worked, with the frequency of reversal of magnetism, with the wave form of the applied electromotive force used in the test, and with the temperature of the test sample. The hysteresis-loss is greater as a rule in hard steels than in soft steels. It varies approximately as the 1.6 power of the induction, and directly as the frequency. It is greater with a flat-top or a sine wave electromotive force than with a peaked or a saw-toothed wave.

Several instruments have been devised for measuring the hysteresis-loss in steel. The Ewing hysteresis meter is probably the best known and most used. With this instrument, samples weighing only a few ounces are required for the test, the measurements being made at a fixed induction, and the instrument calibrated so as to read direct in some convenient unit. A complete description of this instrument and the method of its working may be found in the *Journal of the Institution of Electrical Engineers* (London), Vol. 24, page 398. Other instruments employing the same general principle or entirely different methods are available for measuring hysteresis-loss, but as these may all be found in the text-books of the day their description will not be given here.

Hysteresis measurements are valuable as showing the effect of annealing, but as it is very difficult in practice to separate the hysteresis-loss from the eddy-current loss and as the total loss under working conditions is the point of vital importance to the user of the steel, measurements of hysteresis-loss alone become, in general, of secondary importance.

Eddy-Current-Loss—By eddy-current-loss is meant the loss due to the circulation of electric currents in the sheets themselves and between adjacent sheets, due to the steel acting as a conductor in an alternating magnetic field. The eddy-current-loss varies inversely as the ohmic resistance, directly as the square of the induction, and decreases as the temperature increases. It is greater in thick sheets than in thin sheets, and is greater as the insulation between adjacent sheets is less. Tests for eddy-current-loss alone are difficult to make, and as far as the writer is aware, no instrument has been devised for this purpose. An approximation of the amount of eddy-current-loss in a given sample can be reached by measuring the total losses at different inductions and assuming that the eddy-current-loss varies as the square of the induction and the hysteresis-loss as the 1.6 power of the induction. For special investigations the eddy-current-loss is sometimes calculated in this way, but commercially such tests are rarely considered.

The measurement of the total losses under working conditions gives the best index of the electrical quality of the steel. As the total loss is made up of the combined hysteresis and eddy-current-losses it is subject to all the variations of each as outlined above.

Measurement of Total Losses—In commercial routine testing as followed out in the sheet steel testing department of the Westinghouse Electric & Manufacturing Company, of which the writer has charge, two separate methods which may be designated as the transformer method and the armature method have been found very satisfactory. In both these methods of testing, commercial conditions of operation have been aimed at in order that the results obtained might be checked with the tests made on similar material in commercial apparatus. The test samples have also been so chosen that they will be available for commercial apparatus later, this effecting a considerable saving of material where many tests are made.

The transformer method has been so-called for the reason that the test sample consists of about ten pounds of punchings of a standard transformer plate, these punchings being built up in the same manner as when used in the transformer. For convenience in handling and winding the test sample, a block carrying the coil has been devised, this block being split and the wires of the coil continued between the two parts by means of mercury cups and contacts. By this means, samples which are built up or plates which are not split may be used and placed on the testing block with the winding in place in a few seconds. The routine tests on such samples consist in measuring the total losses at a given induction and frequency, by means of a wattmeter. For special tests the induction, frequency, wave form, and the pressure on the sample are varied as desired.

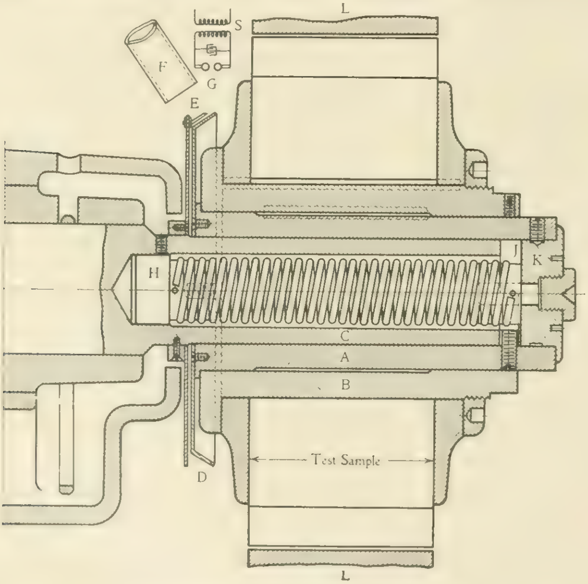


FIG. I—DYNAMOMETER FOR MEASURING ARMATURE LOSSES

This test is used regularly for judging the quality of each lot of steel as received, for judging the quality of the annealing of each furnace load of material, and for determining the aging on all classes of material. From twenty to fifty tests per day are made on this apparatus by one operator. In making tests of this kind the wave form of the applied voltage must be known and should preferably be a sine wave; correction must be made for the copper loss in the magnetizing coil; correction must be made for the losses in the voltmeter and wattmeter, or these losses must be eliminated in the measurements; the test samples must be at approximately uniform temperature.

The armature method is so-called for the reason that the test sample consists of standard armature punchings, which are revolved in a standard form of dynamo field. The measurements are made by means of a spring dynamometer. The photograph of a testing device of this kind is shown in Fig. 2, and a detail drawing of the dynamometer used for reading the losses is shown in Fig. 1. The general plan of this apparatus is as follows:

A small variable-speed, direct-current motor has a shaft extension on which the sample is mounted. The speed is read in terms of voltage across the terminals of a small magneto which is belted to the motor shaft and shown to the right in the photograph. The test sample is revolved in a field having specially wound field coils and adjustable pole pieces. The extension shaft on which the sample is mounted carries a spring dynamometer with a special device for reading the deflection on this dynamometer when the sample is in motion. The sleeve which carries the sample is provided with heavy flanges and is adapted to be placed in an hydraulic press so that any desired degree of pressure may be reached and maintained on the sample during the test.

The very unique spring dynamometer used in this device was designed by Mr. S. M. Kintner and deserves special notice. As will be seen from the drawing (Fig. 1), the hollow shaft, *C*, contains a spiral spring, *J*, the inner end, *H*, being rigidly held to the shaft, while the outer end is fastened to the sleeve, *A*, on which the sample is mounted. The shaft carries a pointer *E*, and the sleeve a circular disc, *D*, approximately eight inches in diameter, graduated on its beveled face in a uniform scale to small divisions. In close proximity to the scale is placed a spark gap, *G*, which is in series with the secondary of the induction coil, *S*. The primary of the induction coil is connected to a contact device on the motor shaft, the break point being exactly in line with the pointer, *E*. Leyden jars are used across the secondary of the induction coil to cut down the duration of the spark. The scale and the pointer are shielded from the light of the room, and a tube, *F*, is provided for observing the scale and pointer at the exact angular position occupied when the spark passes across the air-gap, illuminating the scale and pointer for an instant at each revolution of the shaft. By this means it is perfectly feasible to read, to a high degree of accuracy, the deflection of the spring when the scale and pointer are both revolving at a speed of from 1 000 to 2 000 revolutions per minute.

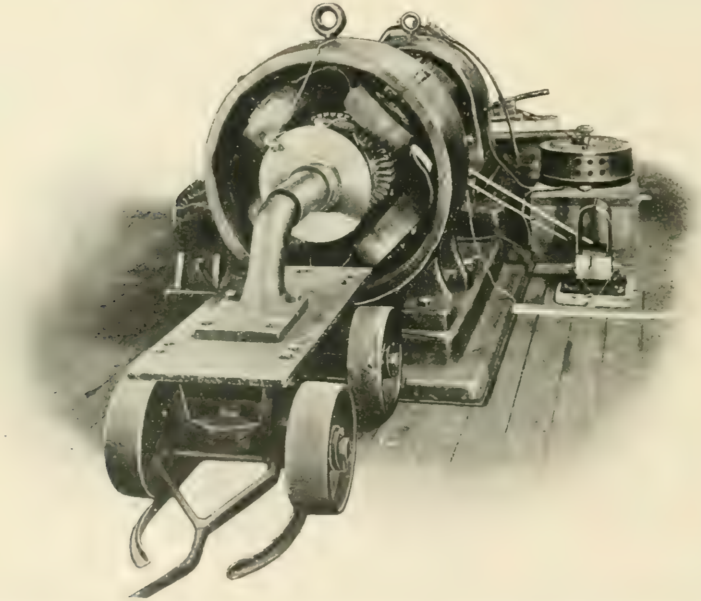


FIG. 2—SHEET STEEL TESTING DEVICE—ARMATURE METHOD. TEST SAMPLE AND CONTACT DEVICE SHOWN IN POSITION

The bearing between the sleeve and shaft is nicely ground and well lubricated, so that there is practically no friction whatever when the test sample is in motion. The apparatus is calibrated by measuring the torque on the spring for an observed deflection. The loss in the sample is then measured in terms of torque and speed, reducing this, if necessary, to the ordinary units of watts per pound in the test sample. For comparative work this reduction is not necessary.

By varying the field strength, the air-gap, the form of pole pieces, the speed and the pressure on the sample, tests under a wide range of conditions are obtained. The windage may be measured by taking readings on the dynamometer with no current in the field. In special tests, complete curves are taken at varying speeds and field currents. In routine tests only a few points are taken.

For convenience in handling the samples, which, together with the sleeve, weigh approximately 125 pounds, a special truck, shown in the foreground, Fig. 2, has been devised, by means of which the sample can be carried about and very quickly placed in position on the testing shaft with a minimum amount of labor.

The above apparatus is used for determining the quality of armature steel as received and the quality of the annealing. It forms a most convenient method of studying the variations in armature losses due to varying conditions, such as pressure, insulation between sheets, variation in induction, variation in form of armature slot, etc. The actual induction may be measured by means of a special coil slipped on the armature punching, the leads of which are brought out to a contact device mounted on the special truck used for carrying the test samples. This device has been in constant use for several months and has been found so satisfactory that it may be confidently recommended to those desiring to make similar tests.

(c) TESTS FOR AGING—It was discovered about ten years ago that when sheet steel is annealed so as to have a low loss and then subjected to a temperature of from 80° C. to 100° C. the loss sometimes increases, in some special cases this increase being as much as 100 per cent. in ten days. Fortunately such cases are rare, and ordinarily the increase is small or there is no change whatever in the loss.

As the aging depends on the kind of material used and on the heat treatment to which it has been subjected, it becomes very desirable to make regular routine aging tests on all steel used for electrical purposes. This is all the more necessary as it is practically impossible to always get steel which has been subjected to identical treatments. These aging tests consist merely in repeating the measurements for total losses at certain definite periods of time after the initial tests, the sample being subject in the interim to the aging temperature. Tests after ten days and after thirty days in the aging oven usually give the necessary data for judging the quality of the material. For purposes of investigation, longer tests are frequently necessary, especially when the effect of temperatures lower than the regular aging temperature is desired. In the tests with which the author is familiar, aging tests are frequently run for six months or a year, and some special tests have been in progress for approximately ten years.

The transformer samples are usually used for the aging tests on account of there being less material to handle and the tests being more easily made than with the armature samples.

The aging oven used for these tests consist of a large wooden box covered on the outside with galvanized iron and lined with asbestos. Steam coils are located at the bottom and ventilators are provided at the top and bottom so that a slight circulation of air may be secured to equalize the temperature. Steam at 150 to 180 pounds pressure is used for heating. The oven is divided into two parts, one of which runs normally at a temperature of very approximately 95° C. and the other at 60° C. to 65° C. These temperatures are maintained year in and year out, and the oven usually contains from 100 to 200 samples which are undergoing the aging test. The temperatures mentioned were selected for the reason that the higher temperature is comparatively easy to maintain and gives comparatively rapid aging when a material is found which is subject to aging, and the lower temperature represents very approximately the temperature at which ordinary electrical apparatus will run under normal working conditions.

(d) PERMEABILITY TESTS—As stated earlier in this paper, the permeability of sheet steels used for electrical purposes varies over comparatively small limits, and the exact permeability of a particular sample is ordinarily not of great importance. It is not customary, therefore, to make routine tests for permeability. Occasional tests are advisable, however, and for this purpose a modified permeability meter designed by Messrs. Lamb and Walker and described in the *Journal of the Institution of Electrical Engineers* (London), Volume 30, page 930, is generally used. This instrument arranged for measuring solid material in the form of round bars is shown in Fig. 3. For measuring sheet steel, the form of the coil and sample holders are changed so as to take rectangular sections. Strips of steel to be measured are sheared to the proper dimensions and clamped in blocks made for the purpose, the measurements being made exactly as in the case of solid material. With this instrument a complete permeability curve with hysteresis loop may be taken in a comparatively short time. The accuracy is not

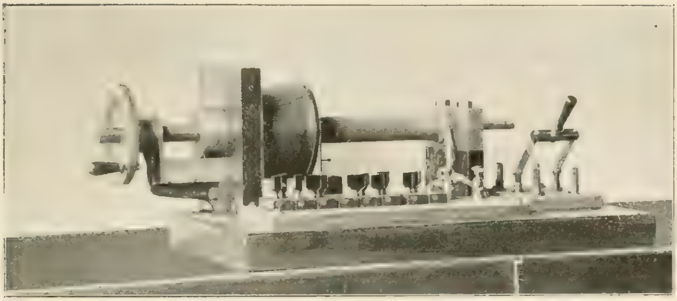


FIG. 3—PERMEABILITY-METER—LAMB AND WALKER PATTERN

as great as with the well-known ballistic method, but it is sufficiently accurate for the purpose and the tests are much easier to make.

The intention of this paper has been to bring forward some methods of testing which are in daily use and which have been found very satisfactory for the purpose for which they are intended. They are not laboratory methods, as the term is usually understood, but they are capable of giving valuable results from an investigation standpoint, as the results obtained may be applied directly to commercial apparatus. It is evident that any work that can be done to reduce the losses in electrical steel and prevent aging when the losses are reduced will be of great value to all manufacturers and users of electrical apparatus.

THE BUSINESS SIDE OF ENGINEERING*

By ALEXANDER C. HUMPHREYS

President of Stevens Institute

THE engineer, to be practical, must be trained in business methods. The use of the word practical in qualifying the word engineer should be considered redundant. It should be understood that a man is not an engineer unless he is practical. But, unfortunately, the use of the word in this connection is found to be necessary. It is again unfortunate that the word practical, as thus used, is not always employed in the same sense. Sometimes it is used to distinguish between the rule-of-thumb engineers and the educated engineers who may be practical in fact; and sometimes it is used to distinguish between two classes of educated engineers, those able to practically apply what they know and those who cannot render effective what they do know. * * * The man who is qualified in pure science, but has not had the experience to enable him to put his knowledge into efficient practice, cannot claim to be an engineer. On the other hand, the man whose lack of knowledge of current science prevents him from doing anything except rule-of-thumb work cannot be considered a practical engineer because his practice is almost sure to be faulty unless it is confined within the narrowest of limits; and when within those limits, discoveries may at any time be made which will render that practice obsolete. He may be a mechanic or craftsman, but he is not an engineer.

The engineer then must be qualified to apply through the craftsman, the mechanic and the laborer, the known laws of nature as applicable to his particular branch of engineering and as further disclosed to him from time to time by the man of science and research.

Would even this be sufficient to qualify a man as a practical engineer? Not unless his engineering plans and designs take full account in each case of the limiting commercial conditions, and not unless his practice is found by comparison to be efficient and economical. It is because men claiming to be engineers have been so often found to be inefficient and uneconomical in their practice that

---

*Abstract of an address delivered before Sibley college, Cornell University, and printed in full in the *Sibley Journal* for May, 1904.

business men are inclined to discriminate in favor of so-called practical engineers and against so-called theoretical engineers. In such cases we find the term theoretical engineer used by way of reproach, because the one using it fails to recognize that work which is to be done in advance of an established practice must be based upon theory and fails to see that a man should not be reproached for following a theory—but he should be so reproached only when he acts upon a partial or incorrect theory.

And here is where the practical ability of the engineer first is employed; namely, in the fitting of a correct and complete theory to the work in hand. In each case theory and practice must be adjusted with regard to each other. To-day the engineer must aim at a high degree of efficiency; he must not employ his power wastefully. He must go farther; he must develop the maximum of efficiency, from the minimum expenditure of capital, all things considered.

Then to be efficient—that is, to be practical—in the management of important engineering work, the engineer must be qualified by training and experience to conduct his work in conformity with commercial conditions, limitations and methods. Unless he knows, understands, takes advantage of and guides himself by the established usages of the business world he must of necessity waste energy, time and money and so suffer from the competition of those who are better equipped.

I hope you men will be inclined to criticise me for taking so much time to establish this point for the reason that you have no desire to disagree with me. But from my past experience with engineering students I can hardly hope that you are all yet prepared to believe that the engineer needs to be trained in business conditions and methods.

* *

In this connection let me quote one paragraph from a recent lecture by Mr. W. M. McFarland before Sibley College:

"The machinery for waterworks pumping engines offers a field for consideration of the commercial aspect. If the pumps are located in a district where coal is very cheap it is easy to see that elaborate refinements to secure great steam economy may represent a financial loss, while on the contrary, where coal is high, it pays to get the most economical machinery. In other words, the engineer when scheming his general plan of machinery ought to make up comparative statements which would include not only the cost of fuel, but the interest on the first cost and allowance for depreciation, repairs, etc. The machinery which represents the lowest aggregate of these annual costs will be that which is best to use."

All this is self-evident as stated.

But, unfortunately, too many engineers lose sight of this truth when the necessity for its application appears, and many others who are prepared to acknowledge that such commercial limitations and conditions should be carefully considered, find themselves, by reason of inexperience in the matter of business methods, incapable of putting into effect the truth which they accept.

I have frequently met this weakness in my young engineering assistants. * *

I shall now speak to you of the necessity of an engineer being qualified to take cognizance of commercial limitations and conditions through his acquaintance with business methods. * * * In nearly all engineering work, and especially in the operation of industrial works, it is necessary to meet intelligent competition. This means that we must be constantly on the lookout for improved and more economical methods of production. If there is a chance for improvement we must discover it and avail ourselves of the opportunity.

But how shall this be done if we concern ourselves only with the results as to product and cost and we do not keep accurate, detailed record of the work step-by-step. We may quite readily, perhaps, be able to find the final cost of a complete piece of work—though even this is too frequently neglected—but we cannot learn the cost of each step of the work except by a system of account-keeping adapted to the particular work in hand. Unless we can by analysis of such a detailed account of cost determine with accuracy the cost of each step in the process, how shall we discover the wasteful steps; and if we do not locate them how can we correct them?

But, you may reply, this can all be left to competent accountants. So it could be after the competent accountants are found. Who shall say that they are competent? If you were a manager of a manufacturing establishment, would you be prepared to take an accountant on faith? The other employes you would expect to select through the exercise of your trained judgment. The managing engineer does not need to be an expert bookkeeper, but he does need to have a knowledge of the principles of accounting. He should be able to direct, or at least intelligently criticise, the accounting methods followed in the keeping of his concern's records. This is a matter of vital and final importance. * *

In connection with shop cost-keeping and the determining of the makeup of that important account sometimes called Profit and Loss and sometimes Loss and Gain, one very important feature enters in with nearly every business, namely, that of depreciation.

Many a concern has gone along serenely paying out dividends in ignorance of the fact that they were not earned; the fact being that these dividends were paid from capital because depreciation had not first been covered from the earnings.

Many a concern which shows a profit for a given period would show a loss if the statement of assets and liabilities were corrected to show the reduced value of the plant, accounts receivable, bills receivable, goods in store, partly manufactured goods and raw material.

Again you say, this is all business judgment and common sense and does not require a knowledge of accounting to enable one to exercise a wise control. But bear in mind that the record of all facts will appear in books which are kept by methods unfamiliar to you, and you cannot, therefore, consider them first hand. I am only arguing in favor of the engineer having such a knowledge of accounting that he can intelligently consider an accountant's statement.

Let me say I am not expressing opinions; I am speaking from a wide experience in the management of industrial properties and in the conduct of a large business in constructing and consulting engineering. Many a time I have reluctantly been obliged to decide not to promote some junior engineer because he could not or would not see that the engineer must also be competent as the man of business unless he is satisfied to remain in a subordinate position. Of two men considered I have frequently passed over the man who was the stronger as an abstract engineer, because the other man had the horse sense and business ability to apply his science to the best advantage in meeting the conditions from time to time developed. Where I have used the term abstract engineer, the custom generally is to say theoretical engineer, but I hold that just as soon as a concrete example comes up for consideration the practical engineer must be able to establish the correct theory for the particular case and in this sense we cannot distinguish between the theoretical and practical. As I have before said, the efficient engineer must be practical and theoretical. * *

I could, if I had time, give you case after case from my own experience, where in the examination of large properties in connection with proposed change of ownership the combined training in engineering and accounting has been required to prepare a correct statement of values within the time allowed.

I could give you example after example out of my experience in the management of a parent company to show that only by a combined training in engineering and business methods could the system of united and uniform management have been developed and maintained.

There is another feature in connection with accounting which should be referred to. The manager must develop the ability to intelligently analyze data as furnished from the records and books of account. This, by the way, is an excellent training in connection with the consideration of the strictly technical side of his work. * *

Another line along which the engineer should acquire some experience is in that of commercial law, especially in connection with the making of specifications and contracts. Engineers would not furnish much business for the lawyers if their specifications, contracts and correspondence were first carefully considered and then made to express just what was intended.

And this brings us to another important feature in an engineer's mental equipment: a good working knowledge of his mother tongue. He should be able to express himself clearly, correctly, explicitly and forcibly. If he can acquire some measure of elegance so much the better, but first let him be sure that he is expressing without ambiguity what he has in mind. There will be an additional advantage in steady effort in this direction, for he will probably discover while there is yet time to correct the fault, that his subjects are not as clear in his own mind as he had supposed.

I wish I had time to give you some of the results obtained by analysing a year's correspondence of a large parent company to determine how much of the letter writting was necessitated by the original or initiative communications having been ambiguous or incorrect. Let me say that the correspondence would have been reduced to less than one-fourth of its actual volume if all communications had been made correct and explicit in the first instance. The tabular exhibit of the facts placed before those concerned materially helped to correct the evil.

Within a few weeks I was presiding at a conference of engineers in which the subject of consideration was the development of a special course of instruction to meet the needs of a certain business. Every man in the room stated that in his opinion the teaching of English was of more consequence than the teaching of any other subject. Each man had come to the conference with the intention of expressing this opinion expecting to have all the others disagree with him. As one man put it: "I prefer to have my assistants know little and be able to clearly show how little they know than to leave me in doubt as to what they do know and what they do not know."

It certainly will be conceded that the making of correct estimates of cost is well within what should be expected of the engineer.

The man who after his work is completed studies the book records of cost and compares the actual cost, item by item, with the estimated cost, is training himself in the best possible way to make correct estimates in the future. And it is very seldom that the man who does not understand business methods can prepare reliable estimates of cost. It is for this reason that when engineers present their estimates for the performance of some large work that we so often hear the hard-headed men of business suggest that as it is an engineer's estimate, fifty per cent. or one hundred per cent. should be added. And too often the engineers by their woeful lack of business ability have furnished sufficient reason for these criticisms.

There is another practical advantage to be obtained from the detailed comparisons of estimates with cost sheets. The engineer who so compares his estimates with his results is training himself to follow the most economical methods in future.

In my business experience I have found that the young engineers who came to me for employment were not only deficient in knowledge of business methods, but they often found it difficult to believe that the engineer should have such knowledge, and some were unwilling to so believe even under pressure. Not a few were convinced only when they found themselves outstripped by their fellows of more open mind.

* *

When I began my work at Stevens I found that the first and most important step was to convince the students of my classes that this subject is one which the engineer cannot afford to neglect.

I feel that if I suceed in convincing my students on this point during their senior year and nothing more, I have saved many of them from serious and perhaps irrevocable loss in connection with their post-graduate training in the field of practice.

I include in my course accounting, depreciation of plant, shop cost, analysis of data and statistics, and commercial law, especially as bearing upon contracts. In connection with work along these lines, I weave in, as far as possible, hints as to business methods in general, and in particular I try to show the great desirability of an engineer making his communications, specifications, etc., self-explanatory and free from ambiguity.

I feel that if these men can be convinced of the real value of study in this direction they can, with their well-disciplined minds, quickly make good their deficiencies in connection with their daily experiences. But if they obstinately and stupidly refuse to see the necessity for this knowledge, they of course will remain in their ignorance and so be forced to remain in subordinate positions as employes of men of broader mind. There are exceptions, but it is hardly safe for any man to calculate upon his being able by reason of exceptional ability to rise superior to rule.

I venture to prophesy that 95 per cent. of the engineer students who are now listening to me will within five years of their graduation, if not before, agree to my proposition.

I further prophesy that most of those included in the remainder —if there be any remainder—will by that time have demonstrated that their opinions are not of much worth beyond some very narrow limits.

If I were asked to express an opinion as to where there was the best opportunity to improve our courses in engineering, I would not speak of the necessity for better equipment to illustrate the specialties in engineering so rapidly and so forcibly coming forward for recognition, but I would say that the improvement might first better be looked for in three directions:

(1) Greater thoroughness in the fundamentals of mathematics and science.

(2) A greater amount of practical instruction in English.

(3) Instruction in the commercial side of engineering and in business methods particularly as bearing upon engineering practice.

Part of this, I have no doubt, sounds very sordid to some of my hearers. But I venture to hold the opinion that instruction in the business side of engineering offers the best possible opportunity for training engineer-students in the ethics of their profession.

I say this though I am fairly familiar with the arguments against the introduction of commercialism into the curricula of our institutions of higher learning.

I contend that the first point to be aimed at in education is to equip the students to be self-supporting and so self-respecting.

I contend that in adding instruction in business methods to the engineer-students' curriculum we are also increasing the chances of developing our students as all-around men.

It is a decided step in the direction of true culture if we can lead our disciples to look at things from all points of view and especially from that of the other man.

It is right then that we should point out to the engineer-student how he can best do his whole duty to his employer and to the community.

* *

From my experience as an engineer, business manager and educator I am firmly of the opinion that such a course of instruction in business methods as I have outlined increases the technical and practical efficiency of the course and it greatly increases the opportunities for the students to gain in culture.

WINDING
A DIRECT-CURRENT GENERATOR ARMATURE

By ARTHUR WAGNER

IN THIS article will be described the connections and construction of the armature winding of a direct-current generator of standard design. The armature has coils formed from copper strap and the winding is of the multiple-circuit type, in both of these respects typical of the larger sizes of direct-current armatures.

DESCRIPTION OF THE WINDING

The armature has 80 slots, in which are placed 80 complete coils, two sides of two coils per slot, or what is commonly called two coils per slot. Each complete coil consists of three single coils of one turn each. The complete coil is made by forming the bare strap on a cast-iron former, the single straps are separately insulated from each other, after which the complete coil is insulated. The shape of the coil is shown in the photograph, Fig. 6. The rear end is of the "involute" shape, and the front end is of the "diamond" shape. The shape of the end connections of the coil is determined solely from mechanical reasons.

Each complete coil contains six conductors, by conductor meaning one side of a single coil. There are, therefore, 480 conductors in the winding. The complete coil has a "throw" of 1 and 13, i. e., one side of a coil is placed in the bottom of slot No. 1, and the other side of the same coil is placed in the top of slot No. 13.

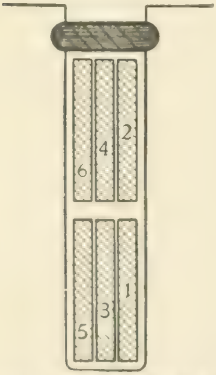


FIG. 1 — ARRANGEMENT OF CONDUCTORS IN SLOT

Fig. 1 shows the armature slot containing six conductors. For convenience in explaining the diagram of the connections of the winding the conductors in the slot will be numbered in the order shown. The three conductors of the bottom side of the first coil will be 1, 3 and 5. Fig. 2 shows the connections of part of the winding. Conductor No. 1, in the bottom of slot No. 1, is connected by the rear cross-connection of the coil to conductor No. 74, in the top of slot No. 13. This conductor is connected by the front connections and through a commutator bar to conductor No. 3, in the bottom of slot No. 1, adjacent to conductor No. 1. Conductor No. 3, in turn, is connected on the rear to conductor No. 76, which is adjacent to conductor No. 74. This method of connection is continued until the entire armature winding is completed. This type of winding is simple and flexible in its requirements. With two coils per slot any number of slots may be used, although it is usual to use a number which is a multiple of the number of poles, so that there will be equal numbers of conductors in the different circuits of the winding. In designing the winding the throw may be varied within the limits, it only being necessary that the throw shall not differ much from the number of slots divided by the number of poles, in order that the two sides of the same coil shall not lie under poles of the same polarity. With any particular armature, however, the throw cannot be changed from the designed throw without affecting the performance of the machine.

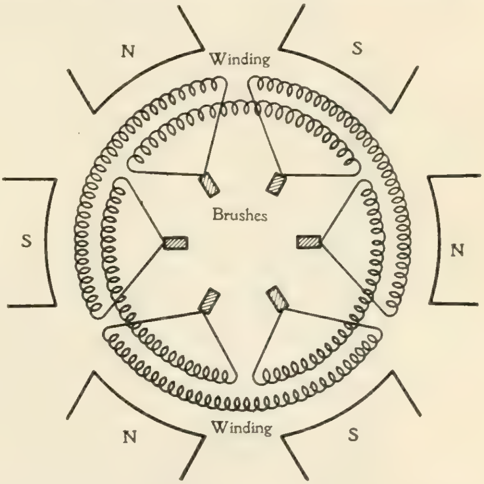


FIG. 2—CONNECTIONS OF A MULTIPLE-CIRCUIT WINDING

The distinguishing characteristic of this type of winding is that the armature circuit between any two adjacent brushes is composed entirely of conductors under two poles. This is shown diagrammatically in Fig. 2 and may be seen actually by tracing out the winding in Fig. 3.

The effects of this arrangement are:

(1) There are as many separate circuits in the armature as there are poles, these separate circuits being connected in parallel by cross-connecting rings on the brush holders. This characteristic gives the winding its name—multiple circuit.

(2) Each of the separate circuits generates independently the total voltage of the generator by the action of the magnetic flux from only two adjacent poles. In this respect, a multipolar generator, say, of six poles, is analogous to three separate two-pole

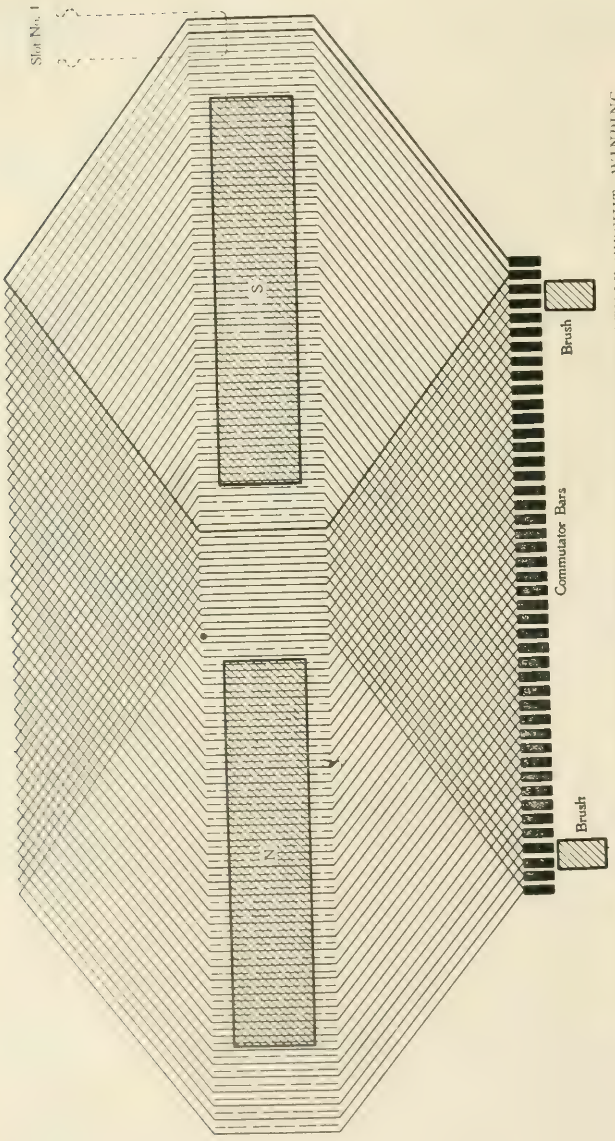


FIG. 3—DIAGRAM SHOWING LOCATION OF DIFFERENT CIRCUITS IN A MULTIPLE-CIRCUIT WINDING

generators connected in parallel and having the same number of conductors in series between brushes.

Balancing Rings—Multiple-circuit armatures, except in the smallest sizes, are provided with balancing rings. These are necessary on account of the fact that the winding consists of a number of circuits connected in parallel, the voltage in the different circuits being introduced by different poles. This necessitates the magnetic flux from all of the poles being the same, so that the voltage induced in all of the circuits will be the same. It is the function of the balancing rings to equalize the field strength of the different poles. This action has been explained in the February issue of THE JOURNAL. Each balancing ring connects together all of the points in the armature winding, which are normally of the same potential, this number being equal to the number of pairs of poles. The number of balancing rings necessary is determined only by experience. The balancing rings may be connected to the winding either at the commutator end or the rear end of the winding. In the former case, the rings are connected to the winding by means of the commutator necks, and in the latter case they are connected to taps taken directly from the end-connections of the armature coils.

In the present case the balancing rings are connected to the winding at the commutator end, as shown in the photograph of the core in Fig. 4. The rings are made of rubber-covered cable, held in position by brass clamps bolted to the armature spider. Short pieces of cable connect the rings to the proper commutator necks, these necks being specially formed to receive the cable connections. There are eight rings each connected to three equidistant bars in the commutator. These connections are shown in Fig. 5, each circle representing a balancing ring, and the numbers, the number of the commutator bar to which the ring is connected.

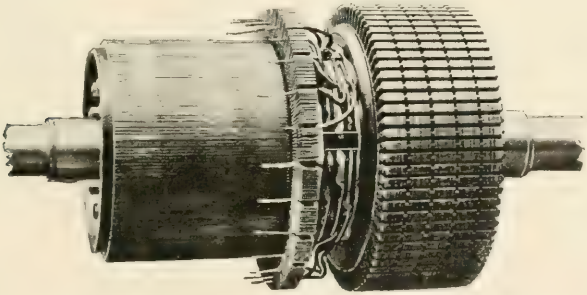


FIG. 4—THE ARMATURE CORE WITH BALANCING RINGS IN POSITION

CONSTRUCTION OF THE ARMATURE

Fig. 4 shows the armature core, commutator and balancing rings assembled and ready for winding. In strap-wound armatures the winding is always done with the commutator in place, to facilitate placing the leads in the commutator necks.

The commutator is first tested completely around its circumference for short circuits between adjacent bars at a voltage of 300, and for grounds at 2 100 volts, both alternating current. This latter test is made by winding a thin copper wire tightly around the commutator and then applying one terminal of the test leads to the armature core and the other terminal to the copper wire. Each armature coil is also tested for short-circuits at 250 volts, alternating current, before being put on the armature core.

When these preliminary tests have been made the core is ready for winding. A piece of cloth is wrapped around the inner edge of the commutator to prevent solder from dropping on the bars behind the commutator necks, causing short-circuits between bars.

Winding—Paraffined-paper cells are placed in the slots to protect the insulation of the coils while winding. In placing the coils the winder stands with the commutator end on his left hand and holds the short side of the coil toward him. The short side of the coil is placed in the bottom of slot No. 1, being driven in place by a fibre drift and raw-hide mallet. The long side of the coil is placed in the top of slot No. 13. The leads of the coil are placed in the proper commutator necks and the ends of the coil trued up. The core, partly wound, is shown in Fig. 6. The arrangement of the leads of one coil is shown in the sketch, Fig. 7. The winding proceeds in such a direction that the top of the core is turned away

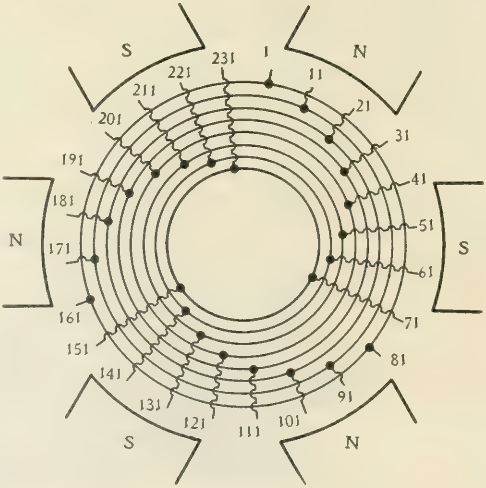


FIG. 5—CONNECTIONS OF THE BALANCING RINGS

from the winder. To put in the short sides of the last twelve coils, which are placed in the bottom of the slots, it is necessary to raise the long sides of the twelve coils first placed on the core, slipping the last coils in under those already on the core.

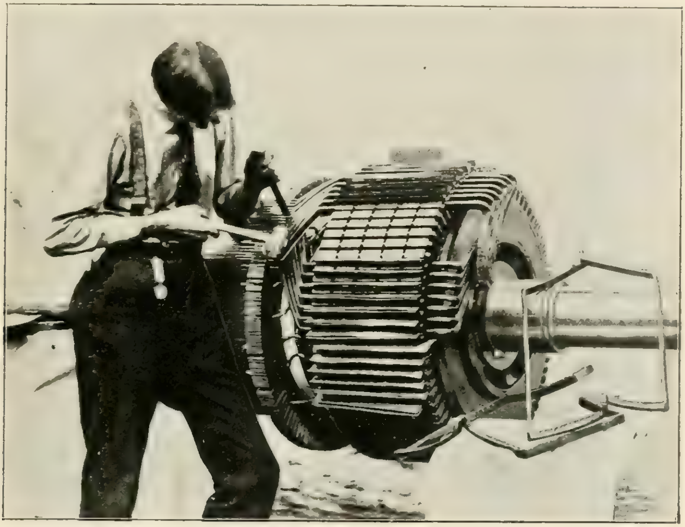


FIG. 6—WINDING THE CORE

When all the coils are in position the projecting tops of the paraffined paper cells are folded over the slot and cut off, and fibre wedges are driven in over the coils. The wedges are in halves, the two halves being driven in from opposite ends of the armature.

At this point the winding is tested for grounds by applying 1 800 volts, alternating, between the commutator and the core.

Preparing the Winding for Soldering—Hard wood wedges are driven between the commutator necks, as shown in Fig. 8. This makes the commutator necks rigid, so that the coil leads can be cut off flush with the outside edge of the commutator neck. Pieces of copper strips as thick as the strap from which the coils are made and of suitable width are driven in the commutator neck between the upper and lower rows of leads to fill the space between the upper and lower sides of the coils.

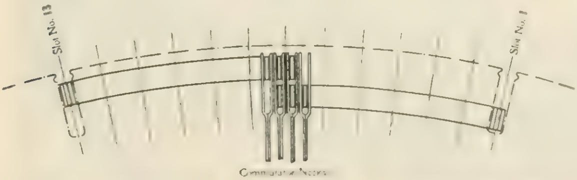


FIG. 7—LOCATION OF LEADS OF ONE ARMATURE COIL

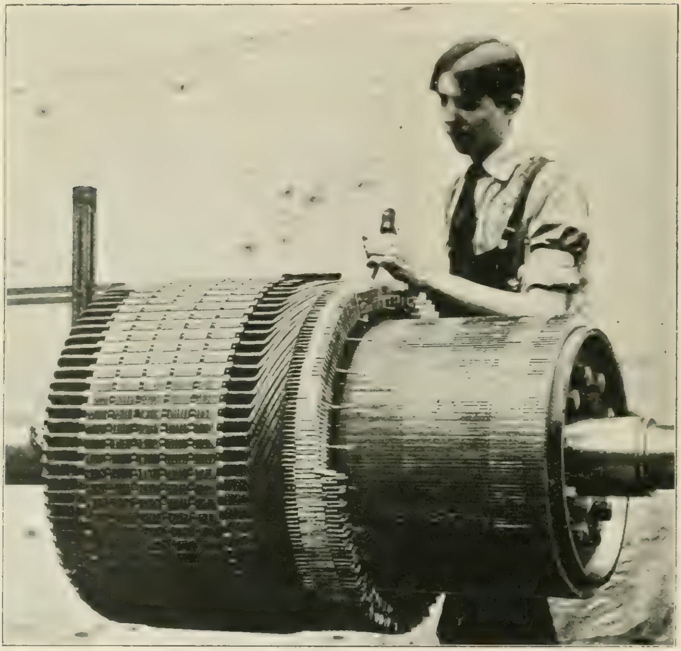


FIG. 8—PREPARING THE ARMATURE FOR SOLDERING

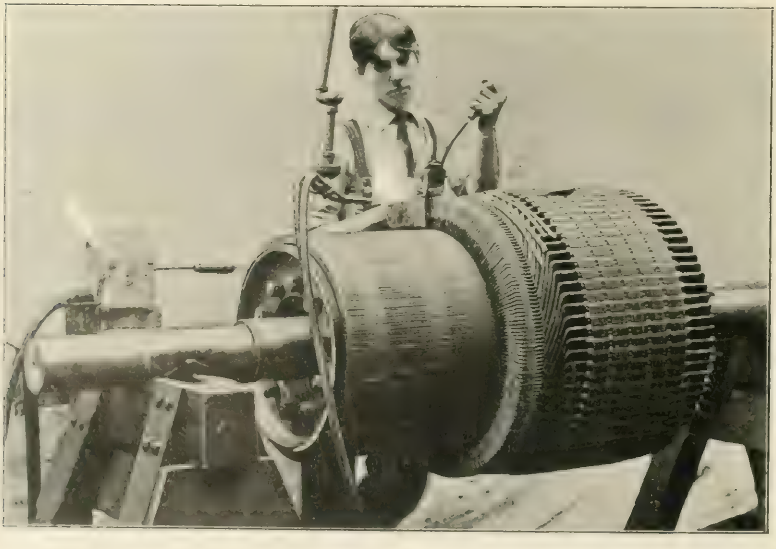


FIG. 9—SOLDERING THE ARMATURE LEADS TO THE COMMUTATOR

The coil leads are now about one-sixteenth of an inch below the tops of the commutator necks. With a flat chisel the top corners of the necks are pinched together (Fig. 8) and thus hold the leads in position and prevent the solder from running out. With a pointed drift about one-half of the wedge is split and driven out (Fig. 8) and the remaining half is driven down below the tops of the commutator necks, this being done to give more room to work in, and to prevent the soldering flame from burning the wood.

Soldering the Leads—In soldering (Fig. 9) a small pointed blast flame is directed on the neck to be soldered, a strip of sheet iron being placed between the necks to prevent the ones just soldered from becoming too hot. After the larger spaces in the neck have been filled with solder, the heat from the soldering iron is sufficient to keep the neck hot, while all the crevices in front and behind are filled, using a slender stick of solder. The cross-connections, which are in every tenth commutator neck and are below the coil leads (Fig. 8), are soldered in as the process continues.

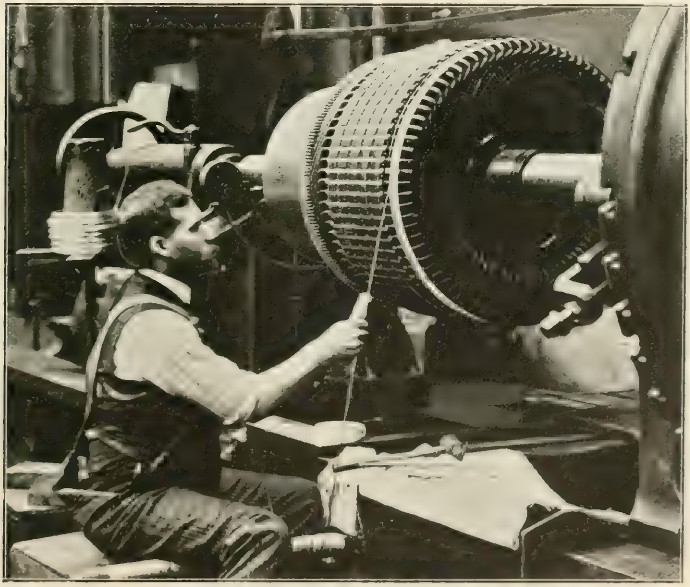


FIG. 10—BANDING THE ARMATURE

Turning Down the Commutator—After soldering, all the half-wedges are driven out and new whole ones are put in, in order that the commutator necks can be turned down in a lathe. Practically no copper is taken off in this operation, so that the necks still extend about one-sixteenth of an inch above the leads. The commutator face is also turned down and sandpapered. The wedges are driven out and the soldered joints filed smooth by hand and the necks carefully spaced. The temporary cloth band, back of the commutator necks, is now removed with a wire hook, and after an examination for small particles of metal, the commutator is tested between bars for short-circuits at 110 volts, alternating.

Banding—The use of fibre wedges in the slots obviates the need of band wires on the armature core, but coils of this shape and size require a band on the rear end. This band is put on by rotating the armature in a lathe, as shown in Fig. 10. Braid insulation is put on under the band wire and the band is kept in place by tin clips. The band is started nearest the core and works away from it; banding in the other direction would cause the outer end of the band to become loose.

Balancing—The armature is statically balanced on a table, as shown in Fig. 11. Ground and polished rings are put on the armature shaft, making a very sensitive bearing. Any unbalance will cause the armature to turn until the heaviest part is the lowest. When the light side is located the unbalance is corrected by casting

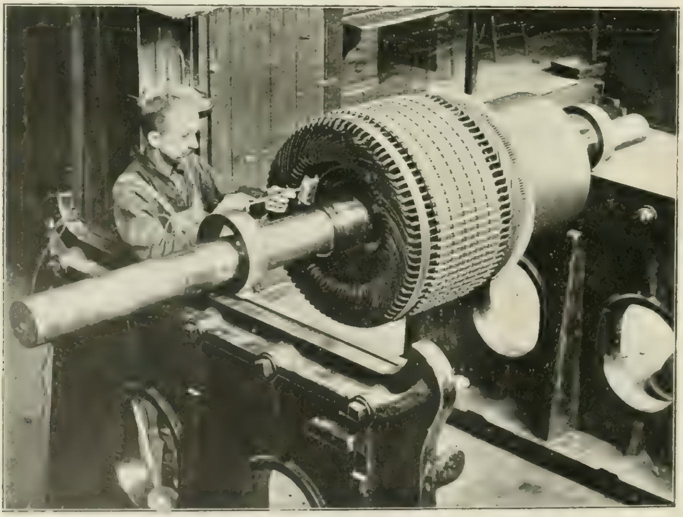


FIG. 11—THE BALANCING TABLE

the proper weight of babbitt in some recess in the armature spider. If there is no suitable place for casting, the babbitt is held in place by screws.

Balancing completes the construction of the armature.

The multiple-circuit winding here described and the two-circuit winding described in the May issue of THE JOURNAL are practically the only types of constant-voltage direct-current windings in use, and, consequently, the only types requiring study by those who desire to obtain a working knowledge of direct-current windings.

FACTORY TESTING OF ELECTRICAL MACHINERY-VI

By R. E. WORKMAN

REGULATION OF MOTORS—In motors designed for constant speed the regulation is the relation between change in speed from full-load to no-load, and full-load speed, with constant current in the shunt field and constant terminal voltage; i. e., if a motor's no-load speed is 920 r. p. m., and its full-load speed 902 r. p. m., under the conditions mentioned above, its regulation is said to be two per cent.

The Drop in Speed in a Motor—Suppose the motor to be running with its brushes on the no-load neutral, and the effect of the armature reaction on the field to be negligible. If the load is increased the motor will be for an instant unable to give sufficient torque to cope with the load and will consequently slow down. This drop in speed, if the motor field strength is constant, causes a drop in the e. m. f. induced in the armature, and consequently a greater difference between the e. m. f. induced in the armature and the line voltage. This allows a greater current to flow in the armature, which, with the assumed constant field strength, will cause a proportionately greater torque, and, if the torque impressed on the motor is not too great, the speed will take such a value as to give a balance between the load torque and that developed by the motor. It will be noticed from the foregoing that the armature resistance determines the drop in speed, since a larger resistance requires a greater difference between induced e. m. f. and the line voltage to allow the necessary current to flow through the armature.

If an increase in armature current causes a change in field strength, due either to series turns on the field poles, or to armature reaction, the speed will momentarily decrease with an increase of load, just as before, but the resulting change in current will alter the field strength, thus altering the counter e. m. f. and causing a change in the speed required for balance between the torque impressed on the motor by the load and that developed by the motor; this change in speed will be an increase if the field is weakened by an increase in current, and a decrease if the field is strengthened by an increase in current. In the case of a cumulatively-wound compound motor, the drop in speed will be greater because the field strength is increased with an increase of load; and in a differentially-wound compound motor the speed on load may be made higher than the no-load speed.

Comparing the effect of armature current on the field in the case of a motor with that in the case of a generator, it will be seen that, since the direction of the current in the conductors is reversed for the same direction of rotation, the cross-magnetizing force will be reversed and consequently the brush lead will have to be backward, and since both the brush lead and the current in the conductors are reversed, the effect of the back-magnetizing force will still be opposite to that of the field turns and the field will still be weakened by the armature current; this tends to keep up the speed of the motor with increase in load if there is back lead on the brushes. The effect of armature resistance, however, is to counterbalance that of armature reaction as described above.

Motors are compounded for one of two purposes: to cause a drop in the speed when the load is increased, giving a greater possible torque for a given load than the shunt motor (one of the characteristics of a series motor), or to obtain constant speed characteristics. The former class are wound cumulatively, i. e., so that the series coils assist those of the shunt and strengthen the field with an increase of load. The latter are differentially wound. The advantage of the cumulatively-wound motor over a series motor is that it cannot run away if the load is dropped. The differentially-wound motor is very seldom used, the advantage of constant speed being seldom great enough to counterbalance the complication of a series winding.

There are three methods of making a test for regulation of motors, the method chosen depending chiefly on the size of the machine.

(a) Belted to a generator, loaded on racks.
(b) Belted to a generator, loading-back methods.
  (i) With a similar machine.
  (ii) With a machine of lower voltage but the same current capacity.
(c) By brake test.

(a) REGULATION OF A MOTOR BELTED TO A GENERATOR LOADED ON RESISTANCE: *Preparations for Test*—The same table is used as in the last tests, connected as shown in Fig. 29. A generator of about the same size as the machine to be tested is belted to it to be loaded on a resistance rack.

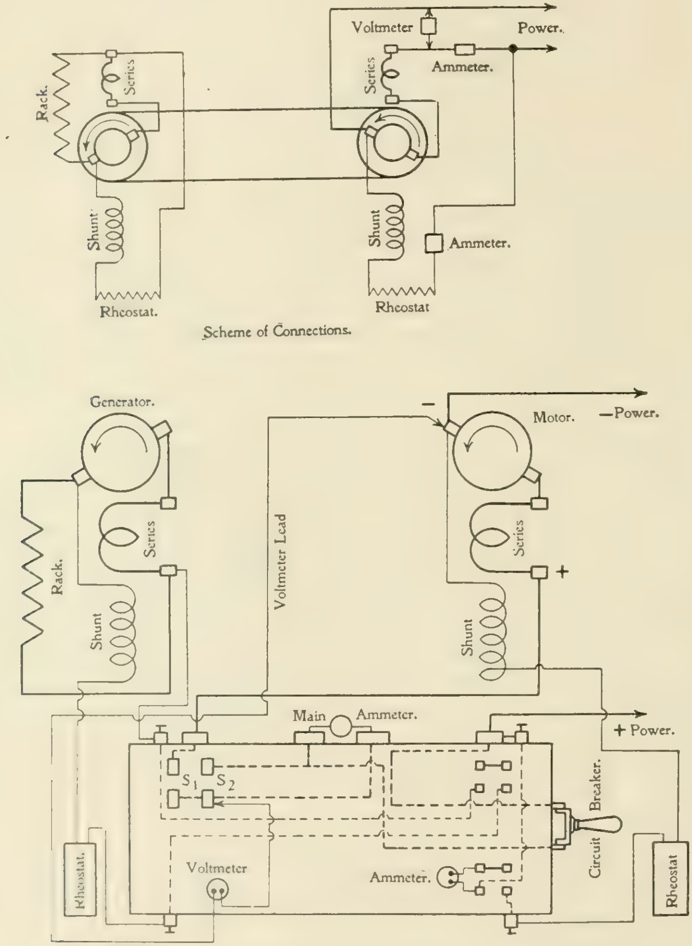


FIG. 29—CONNECTIONS FOR REGULATION TEST OF MOTOR BELTED TO GENERATOR LOADED ON RESISTANCE

Conduct of Test—The motor is started by temporarily putting a starting resistance in the place of the ammeter, the main and ammeter switches being open. The power should now be switched to the table and the motor field switch closed. The starting resistance must be set all in and the main switch closed. The motor will now start, the starting resistance may be gradually cut out and the ammeter switch closed, short circuiting the starting resistance. The brushes should be set at a trial full-load position, which may be done as the no-load neutral has already been found and marked, in the iron-loss and saturation tests. The generator field may now be closed and the generator loaded on the rack. The regulation points will be taken just as in the case of a generator except that speed is now the dependent variable, instead of voltage. The shunt field current and the terminal voltage are held constant throughout the test. The shunt resistance is adjusted at full load so as to obtain the proper speed at that load, and is not changed during the test. As accurate speed regulation is seldom required in compound motors, a shunt to the series windings is seldom used. The readings taken are: armature amperes, shunt field amperes, speed, and terminal voltage.

The working up of results will be described later, as it is the same whatever the method used for loading the machine.

(b) Loading-Back Methods—These tests depend on exactly the same principles as the loading-back methods used with generators. In every case, the voltage on the motor terminals and the shunt field current are held constant while the load is varied. In order that these conditions may be fulfilled it will be necessary to vary the speed of the machines. The curve of speed plotted to external amperes will evidently be the same as if the motor were loaded under running conditions. It will be seen that where a driving motor is used, the speed practically becomes the independent variable, and the external amperes the dependent variable; in other words *the speed of the whole set is controlled from the shunt rheostat of the driving motor.*

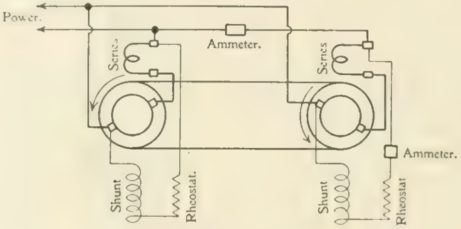
(i) Loading a Motor Back on a Generator of the Same or Greater Capacity and of the Same Voltage—This test is the same as that with a generator loaded back on a motor of the same or greater capacity except in one or two points. The motor being in this case the machine tested, its terminal voltage and shunt field resistance are held constant, instead of the speed and shunt field resistance as in the case of the generator. The speed of the motor is in this case the variable instead of the voltage of the generator.

As before, it will be necessary to see that the series fields of both machines are connected up so as to work in the same way with the current flowing through the two in series.

Preparations for Test—The table connections will be exactly as shown in Fig. 23 (June issue), the two machines being belted together and to a driving motor, as before.

Conduct of Test—The machines will be started up and paralleled in the same way as in the case of loading back a generator on a motor of the same or greater capacity and the same voltage, the only difference in the conduct of the two tests being in the readings taken.

In order to find the amount of resistance required in the shunt field, where the motor is a large one and is to be provided with a shunt field resistance, it is necessary first to take a full-load reading. The speed is made correct by means of the shunt field rheostat of



Scheme of Connections.

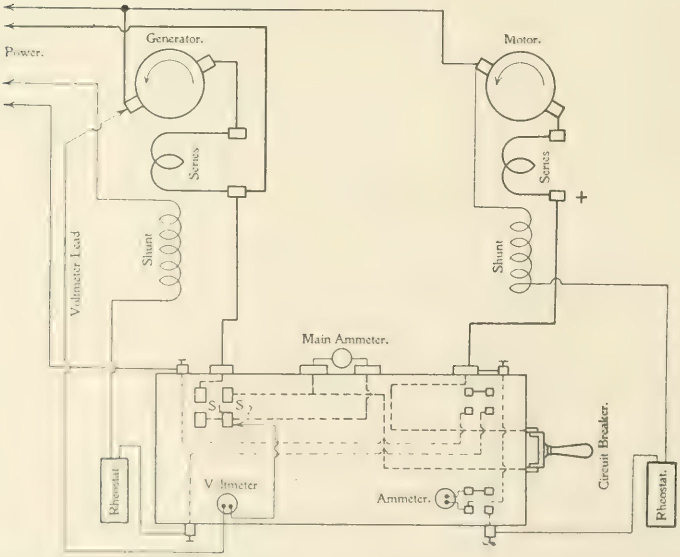
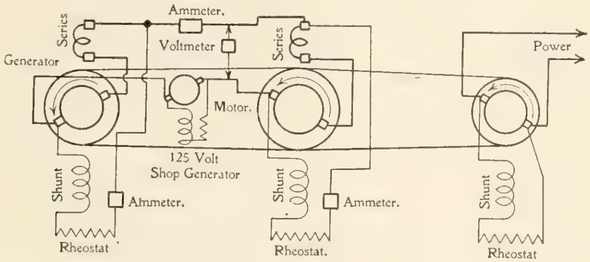


FIG. 30—CONNECTIONS FOR REGULATION TEST OF MOTOR LOADED BACK ON GENERATOR OF SAME CAPACITY AND VOLTAGE

the driving motor and the shunt field resistance of the machine under test adjusted till the proper current is obtained in the armature. This adjustment of the shunt field is held constant throughout the test. A series of readings is taken at various loads, by altering the speed of the driving motor by means of its shunt field resistance. It should be noticed that the current measured by the main ammeter is the external current, not the armature current as in the test with resistance load.



Scheme of Connections.

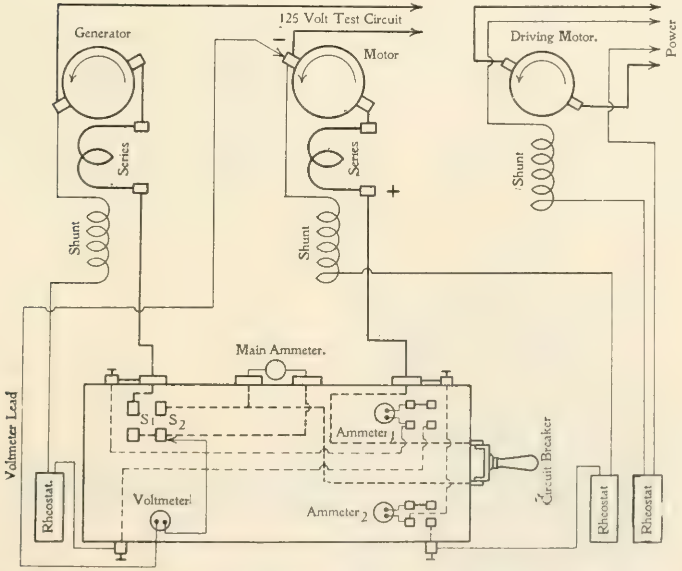


FIG. 31—CONNECTIONS FOR REGULATION TEST OF MOTOR LOADED BACK ON GENERATOR OF SAME CURRENT CAPACITY BUT LOWER VOLTAGE

As in the case of generators, where the line voltage may be adjusted, it is possible to make this test without a driving motor.

The test is practically the same as the analogous one made in the case of a generator.

Preparations for Test—In this case it is convenient to start the set by means of the generator working as a motor and the machines are belted up and connected as shown in Fig. 30.

Conduct of Test—The generator should have its brushes set to run as a motor and may then be started up in the usual manner. The motor is then paralleled as the generator was in the last test, and the brushes set in their proper positions. The test is then proceeded with in the same way as the last, the shunt resistance required being determined as before and held constant throughout.

(ii) LOADING A MOTOR BACK ON A MACHINE OF LOWER VOLTAGE BUT THE SAME CURRENT CAPACITY—In this case it is necessary to boost up the generator voltage from an external source of power.

Preparations for Test—The machines are belted together and to a driving motor, as in the last test. The connections are made as shown in Fig. 31. The series connections must be examined to see that they are correct.

Conduct of Test—The set is started up as in the preceding tests, brought to speed and the brush position adjusted, all circuits of both generator and motor elements being open. The generator field is then closed and the positive of the 125-volt circuit connected to the negative of the motor element. The voltage of the generator is then adjusted to give the proper working voltage of the motor

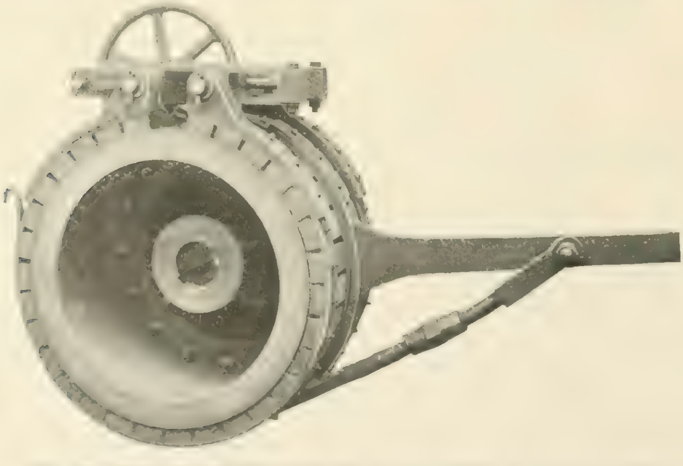


FIG. 32—FORM OF PULLEY USED IN BRAKE TESTS OF LARGE MOTORS

when added to the 125 volts of the testing circuit. The shunt circuit of the motor element is then closed, its voltage brought up to exactly that of the generator element and the main circuit closed. The same precautions must be observed in completing the circuit as in the preceding tests. The regulation is taken exactly as before. In shutting down, the main circuits of the two machines should be broken before that of the driving motor, the load being brought down as before. It should be noticed that the current measured by the main ammeter is again the external current.

(TO BE CONTINUED.)

CORRECTION—On page 298 of the June issue the statements there should be changed to read as follows:

"Above ten amperes per square inch, current density, the drop is 1.25 volts plus .025 volt for every ampere per square inch above 10.

DENSITY AMPERES PER SQUARE INCH	DROP VOLTS
5	0.625
10	1.250
15	1.375
20	1.500
25	1.625
30	1.750
35	1.875
40	2.000

SHOP EXPERIENCE

TEMS FROM THE NOTE BOOK OF THE APPRENTICE

Copper Dampers in Alternating-Current Machines—Alternating-current generators and rotary converters are usually provided with copper dampers on the field poles. The dampers assist in the parallel operation of generators and in the steady operation of rotary converters. In generators having partially closed armature slots the damper is made in the form of a plate; in revolving armature machines the plate covers the face of the pole; in revolving field machines the damper bridges the space between two poles, also serving, in this case, as a wedge to hold the field coils in place. In open slot generators and rotary converters the dampers are of the so-called grid type, surrounding the pole and extending across it, imbedded in slots in the face of the pole. This divided form of damper is better adapted to open slot machines on account of the characteristic "jumping" of the field flux from armature tooth to armature tooth. This action would set up eddy currents in the copper plate which would increase the losses of the machine and which might easily be sufficient to warp the plate so severely as to loosen it from the pole. The copper damper was illustrated in the June issue of the Journal.

Power-Factor Meter Connections—The usual way to connect a power-factor meter to a three-phase circuit is shown in the diagram, Fig. 1.

A, B and C are the three phases of the three-phase circuit. Only two series transformers, A and C, are necessary. The shunt-transformer may or may not be necessary according to the potential between A and B.

Leads c, d and e are connected to what is virtually a two-phase induction motor in the interior of the power-factor meter. It is this motor that, partially counterbalanced by the shunt coil in the interior of the meter, gives torque to the dial pointer. There is no electrical connection between the shunt coil and the motor, so that while current flows readily from c to d and from d to e, no current can flow from either c, d or e to either a or b. Finally, it is important to note that the current in d is the vectorial sum of those in phases A and C.

By placing an ammeter in *d* and by arranging two additional shunt circuits on each side in such a way as to be able to short-circuit the ammeter at will, the current in each of the three phases may be measured by the ammeter with the aid of four ammeter plugs.

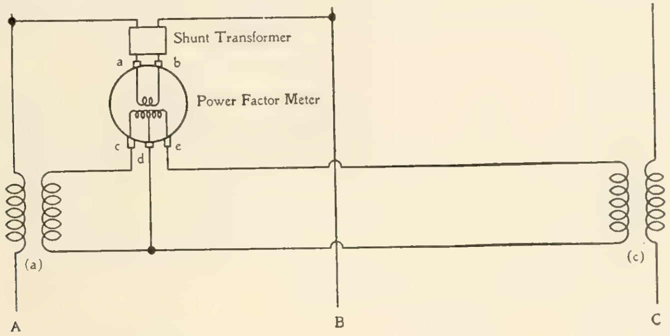


FIG. I—USUAL CONNECTIONS OF POWER-FACTOR METER IN THREE-PHASE CIRCUITS

Thus in the diagram, Fig. 2, by plugging in 1 and 2 the current from phase *C* is shunted away from the ammeter—although still allowed to pass to *d* and thence to the power-factor meter—and the current from phase *A* passes through plug 2 and may be read in the ammeter on its way to the power-factor meter. Therefore, by this arrangement we obtain the current in phase *A* and also the power-factor of the combined circuit.

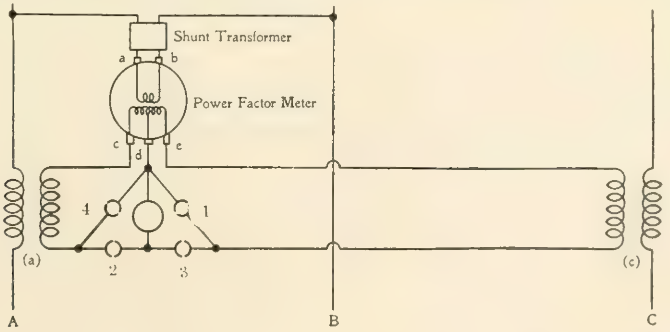


FIG. 2—CONNECTIONS OF POWER-FACTOR METER IN COMBINATION WITH AMMETER

By plugging in 2 and 3 the currents from both phase *A* and phase *C* pass through the ammeter—which registers their vectorial sum which is equal to that in phase B—and from thence into the power-factor meter. Thus by this arrangement we obtain the value of the current in phase B and also the power-factor.

By plugging in 3 and 4 the current in phase A is shunted away from the ammeter—although still allowed to pass to the power-factor meter—and the current from phase C passing through 3 is measured in the ammeter without disturbing the power-factor meter reading.

Finally the ammeter may be disconnected entirely by plugging in 1 and 4 only. This is a safe and convenient way to leave the plugs when not in use. Care should be taken not to pull both 1 and 3 or both 2 and 4 out at the same time, as by so doing the secondary transformer a or that of transformer c will be open-circuited, in which case the primary current will saturate the core, inducing a dangerous secondary voltage.

THE
ELECTRIC CLUB JOURNAL

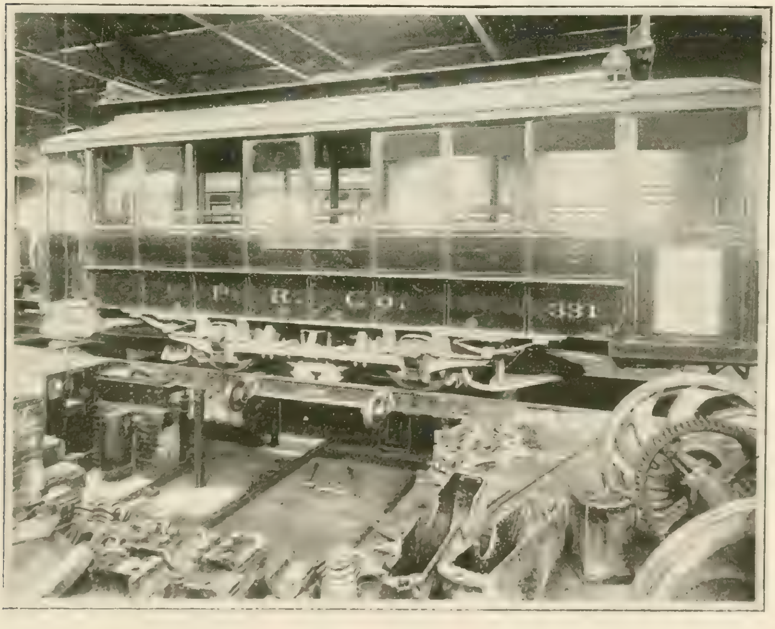
VOL. I AUGUST, 1904 NO. 7

MAINTENANCE OF ELECTRIC RAILWAY EQUIPMENT

By J. E. WEBSTER

THE continual adaptation of railway apparatus to heavier and faster service brings to the operating man new problems in maintenance which can not be wholly solved by the experience of past years. Indeed, new types of equipment construction require often the introduction of entirely new methods and new tools for their proper care and repair.

It is to be remarked in passing that the study of the problems incident to the maintenance of a service is much facilitated by a



REPAIR PIT

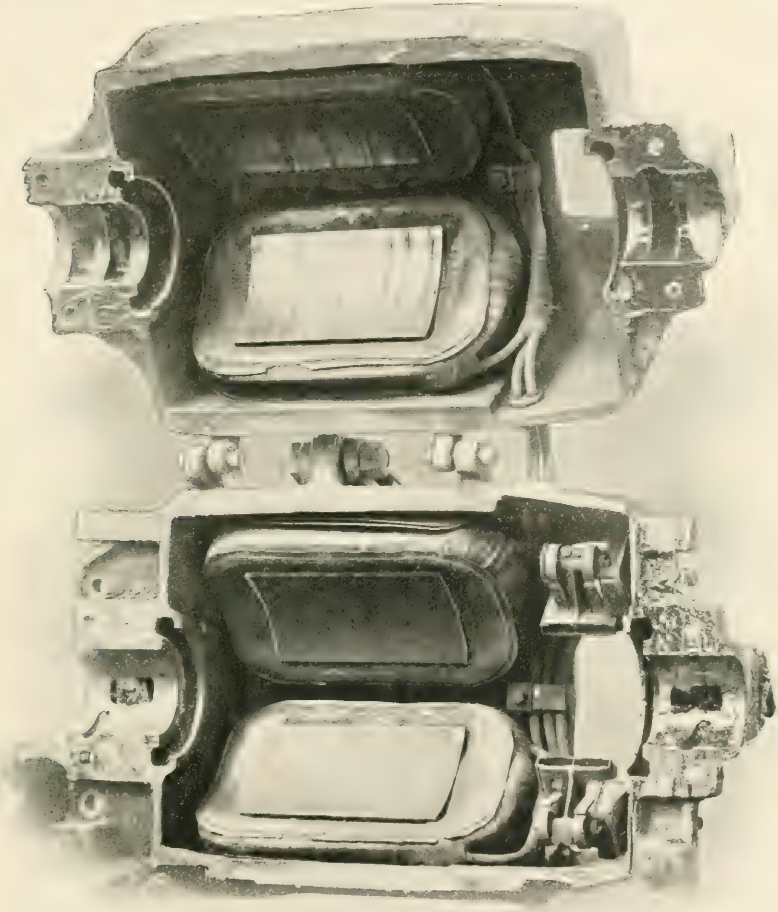
View taken in the Frankstown avenue car barns of the Pittsburg Railways Company complete record of the work done by men and equipment; as, if a trolley wheel costs two dollars it is worth perhaps five cents to ascertain the number of miles it will run. The desirability of such data, even after the wearing qualities of a wheel under good usage are established, is also most useful in checking the efficiency of the care-taker. And if a close record of the performance of trolley wheels is of value, it is equally true that such data should be kept of the bearings, car wheels, brake wheels, brake shoes, armature coils and other apparatus requiring more or less frequent renewal.

Two reliable systems of maintenance are in extensive use. They differ mainly in determining when the equipment shall be taken out of service for general repairs. In the mileage system, which is generally used by large railway companies, the car is taken out of service as often as it has run a definite mileage, about 12,000 miles for interurban service, and somewhat less for city service. Motors and auxiliary equipment are then dismantled and subjected to a thorough examination. In the inspection system, the cars undergo a daily or trip inspection of a thorough character, and are sent to the shop for general repairs only when the wear of wheels, bearings, commutator or other vital parts require it. The respective merits of the systems will not be here discussed, and we therefore proceed to various items of inspection, and first of motor equipment.

Motor Equipment. In the general overhauling of a motor, the armature should be removed and the bands carefully examined for loose wires which, if found, must be replaced. In the process of rebanding, the clips should be placed about three inches apart, well filled with solder, using a resinous flux because acid is very injurious to insulation. The clips should be entirely free from burs.

The armature should be thoroughly cleaned by an air blast if the motor has a ventilated winding and the end of the commutator and the brush-holder arm should be thoroughly cleaned of any accumulation of oil and carbon dust. It is usual to varnish these parts after the process of cleaning is completed. If the commutator is at all worn it is best to give it a thin cut in the lathe, and before replacing the armature in the motor it should be thoroughly painted with an air-drying varnish or insulating paint.

If the brush-holders show wear or burning on the wearing surfaces, they should be thoroughly cleaned and polished, shunts should be properly fitted to the brushes and contact springs adjusted. The field coils should be cleaned, and if at all injured should be removed and repaired. The leads especially need close attention, many a car having been brought to the barn owing to grounded leads. Worn leads may sometimes be reinforced by the use of canvas or rubber hose.



MOTOR WITH DEFECTIVE JOURNALS

A fair representation of many car motors where the poor lubrication has led to the melting of the babbitt metal and allowed the armature to rub on the lower poles. These are shown in the upper portion of the cut, having a polished appearance.

If the daily inspection and care of the controllers is efficient they should require but little special attention at the general overhauling of the equipment. But the tension and lift of contact fingers should be examined, worn rings should be immediately replaced and all insulation should be cleaned and varnished, burned parts being removed.

Bearings. The care of bearings is largely a matter of maintaining constant lubrication, which until very recently has been almost always accomplished through the use of grease. With grease lubrication there are two important points to watch; first, the kind of grease used, and second, the method of application. If the grease is too heavy for the prevailing temperature, a "hot-box" will develop before the grease begins to flow, and it is necessary to keep the bearing hot in order to keep the grease flowing. If the grease is too light, it is apt to run through the bearing and leave it dry. The specific requirements differ so much with motor construction and various classes of service that it is impractical to specify any one thing which is best for all cases. Of course, two cars running under the same conditions may use different lubricants, and then the results can be closely judged; or, if information is at hand concerning the use of lubricants on roads where equipments and service are similar, one may select a lubricant for trial.

As to the second point, the method of application, many men who for some time have been greasing cars will try to force chunks of grease twice as large as the cup into the opening, scrape up all that has been smeared over the gear case and the end of the motor and put that in on top, too, without cleaning the cap or adjacent surfaces from the ever-present layer of grease, brake dust and miscellaneous grit that is to be found in all railway motors after service.

Grease in a bearing melts away from the bottom of the grease cup, leaving an opening for quite a distance above the bearing, requiring the grease to be forced down in the box at frequent intervals. At best, with grease lubrication, the flow of lubricant is irregular, and therefore many special appliances have been arranged for using oil in bearings designed for the use of grease. Some of these use a sheet metal cup that will fit in the grease box with a tube opening from the bottom and passing through the center of the cup to the top. A woolen yarn wick is passed through the tube, having one end in contact with the shaft, while the other (long) end is coiled in the oil cup. The amount of oil which flows is regulated by the number of strands in the wick. Very good results have been reported from the use of this method, although the cup feeds continually while the car is standing over night, thus wasting needless oil and often leaving an empty cup for the morning start.

In other cases a piece of piano felt is fitted against the shaft in the opening of the bearing at the bottom of the grease cup and extends some distance into the cup. The cup is then filled with oil-saturated waste, which is prepared as described in a later paragraph.

Where oil is applied by means of felt wicks to armature or axle bearings, the grade of felt must be very carefully selected. The best is known as piano felt. The portions of the felt which come in contact with the shaft must be frequently inspected, as there is a tendency for the felt to become hard and glazed which tends to stop the feeding of oil. This is particularly true if the oil is allowed to become dirty, the felt acting as a filter and holding the dirt, etc.

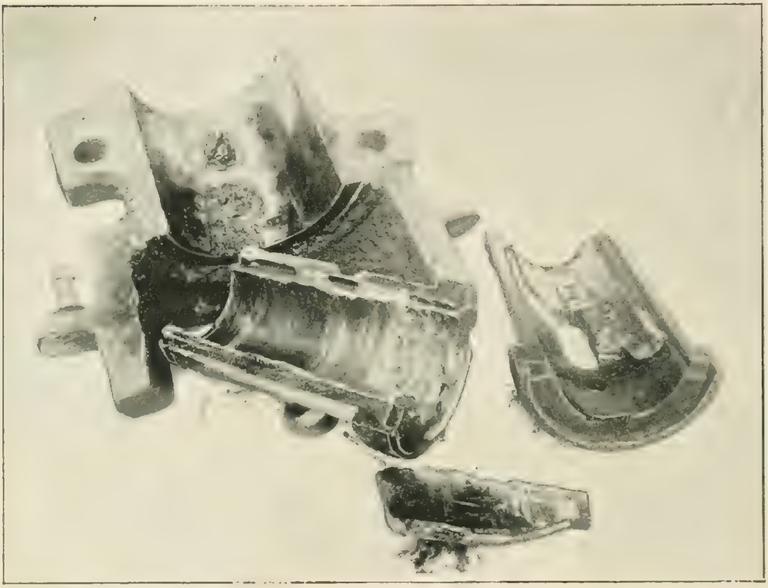
Another method in successful use is to plug the bottom of the grease cup and then drill a hole through the plug 2-1000 of an inch larger than a No. 4 wire. A piece of No. 4 copper wire is then placed in the hole with one end resting on the shaft and the other end extending into the cup. The cup is then filled with oil. The jar of the motor in service allows sufficient flow of oil around the wire to give good lubrication, yet the fit is so close that practically no oil flows while the car is at rest.

Lubrication by Means of Oil and Waste. The use of oil and waste in lubricating railway motor bearings has proven extremely successful and at the present time is regarded as the best practice.

This method of lubrication can, however, be abused by the use of improper materials or by lack of attention. The following points should be observed in caring for bearings operated in this way:

Waste—A high grade of wool waste must be used. It must be elastic in order at all times to maintain some pressure against the shaft, even though the lubricant is applied from below as in motor axle bearings. The elasticity is sometimes increased by the addition of a small percentage of Japanese or India fibre. Cotton waste and poor grades of wool waste become soggy and dead and fall away from the shaft.

Oil—In general, it is good practice to use a good car journal oil of a grade slightly lighter than is used on the car journals at the same season of the year. The lighter oil is used owing to the higher speed of the armature shaft relative to that of the car axle, and also owing to the fact that the waste does not come in contact with the full length of the shaft or axle in the bearing, thus requiring an oil that will flow more freely than that required in the car journals. The oil must not be too light, however, lest the film of oil between the shaft and the bearing become so thin that the wear of the bearing would be excessive. The flow of an oil is affected to a considerable extent by the temperature at which it is used. A lighter grade of oil should therefore be used in winter than in summer.



WORN-OUT JOURNAL

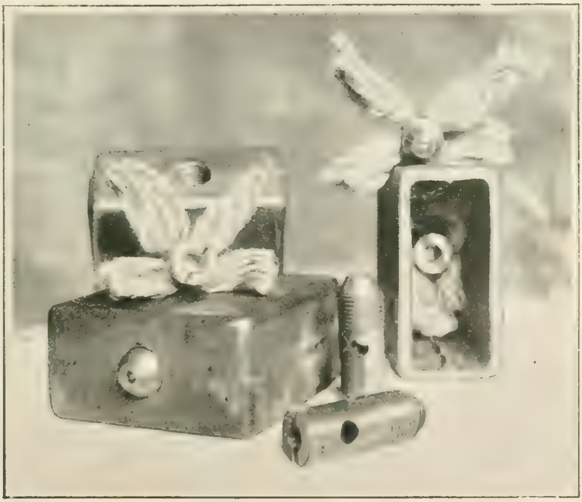
A detail view of the common type of grease lubricated bearings showing the feed wire, also the burned babbitt, which in this case was due to insufficient feed of lubricant.

Application of the Oil—The waste must be thoroughly saturated with oil, as it will not feed by capilliary attraction until every particle of its fibre is thoroughly soaked. Before the waste is packed in the bearings, the free oil should be allowed to drain off, otherwise the excess oil will be forced into the drip pockets and accumulate on the equipment and on the shop floor, and some will also probably find its way into the motor and prove injurious to the insulation. To prepare the waste for use therefore it should be immersed in oil at least 48 hours to obtain the required saturation, and should then be allowed to drip for 10 or 12 hours before using.

Packing Bearings—In packing the bearings care should be taken not to pack the waste in either too tightly, which would force all of the surplus oil out, or too loosely, which would not maintain a proper contact against the shaft or axle. The waste should be formed in loose balls of such a size that they can be placed in or removed from the bearing without the use of undue force.

No free oil should be added when packing. In some cases it may be wise to add free oil in small quantities at intervals during service as the waste becomes dry. But in general this is unsatisfactory. The best method is to change the packing at regular intervals, re-immersing the old packing, if clean and in good condition, in oil for future use. Changing the packing guards against the possibility of the waste, which is in direct contact with the shaft or axle, from becoming hard or glazed and hence interfering with the feed of oil. The frequency of this change can best be determined by careful observation of the condition of packing and bearings in any given service.

Whenever it is necessary to open the lid of the bearing housing for inspection or repacking, great care should be taken to clean all surfaces adjacent to the lid so as to prevent dirt or grit of any kind becoming mixed with the waste.



A NEW DEVICE FOR USING OIL ON CAR JOURNALS

A modification of the siphon-wick type. The lower end of the tube contains a valve preventing feeding when car is not in motion.

As the proper facilities for handling waste for this method of lubrication are a great help in getting results, the following suggestions are made:

For stations where but little waste is used good results can be obtained by the use of two galvanized iron cans 20 inches in height by 24 inches or more in diameter, with one inch cock at the bottom, placed on a bench and arranged so that when the cock is open oil may drip in a trough leading to a third can or barrel. Each can should be provided with a cover and a removable wire screen of No. 12 wire netting, ¾-inch mesh, which is placed three inches from the bottom of the can. In order to give a proper saturation and drainage, the height should not exceed 20 inches as given above. If a large amount of packing is used, the number of cans can be increased accordingly and, if desired, suitable piping may be arranged with a pump for refilling the cans from the drain tank.

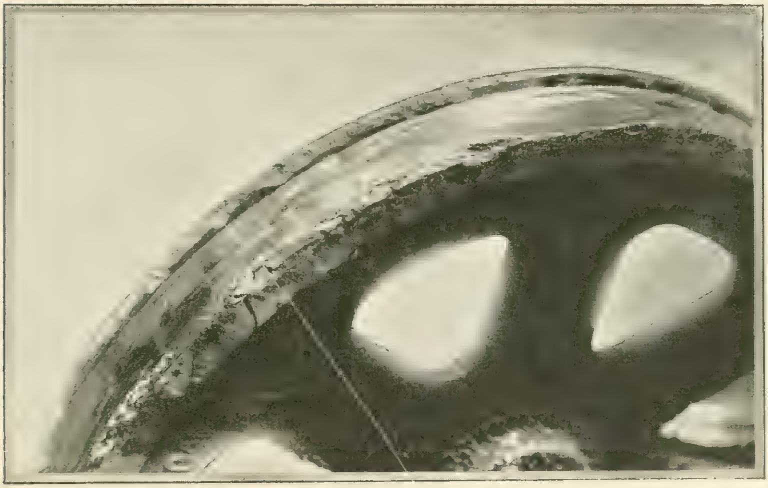
The cans are filled with waste, which is then flooded with oil and permitted to saturate for 48 hours. The cock is then opened and the surface oil allowed to drain off. The tanks should be kept in a room having a temperature of about 70 degrees Fahrenheit.

Journal Boxes.—Waste prepared as above should be used on the journal boxes, very little free oil being added.

RE-BABBITTING BEARINGS. Whenever the bearings become worn so that the armature is dangerously near the field poles, they must be re-babbitted. The kind of bearing metal to be used is a subject that is much disputed. For heavy motors a strong, hard metal of the grade of genuine babbitt metal must be used. For smaller motors softer metals are sometimes used with good results. Care should be taken while casting the bearings not to overheat the metal, as the quality of the metal is very easily affected by high temperatures. Some of its ingredients are readily oxidized and almost entirely disappear if the hot metal is exposed to the air for a great length of time. By keeping a record of the life of bearings it can soon be determined how many times the metal may be cast and still retain its life. To ascertain this result new metal should not be mixed with old. All bearings cast with new metal should be stenciled No. 1; when these are worn, the metal remaining should be recast and the bearings stenciled No. 2. Continuing this as long as the metal is used, the life of the bearings of the different numbers being kept, it will soon be evident when the metal is useless.

The mandrils on which bearings are cast should be as accurate as possible so that but little metal need be turned off in fitting the shell for the shaft, as the cast surface is slightly chilled and gives better life than a turned surface. Many companies do not bore their bearings at all, casting them to the exact size. This requires skilled work and is not easy to accomplish with small concerns, although no doubt it is the best method.

Wheels—For city work and for interurban work, where motors do not exceed 60-horse power, cast iron wheels with chilled treads and flanges are used. Cast wheels are sometimes used on cars equipped with 75-horse power motors, although steel tired wheels seemed to be used in increasing numbers where speeds are high. Where the motors are of 100-horse power and above, steel tired wheels are in almost universal use. Solid pressed steel wheels are now used on a few roads using motors of less than 75-horse power where speeds are at all high.



CAST IRON CAR WHEEL

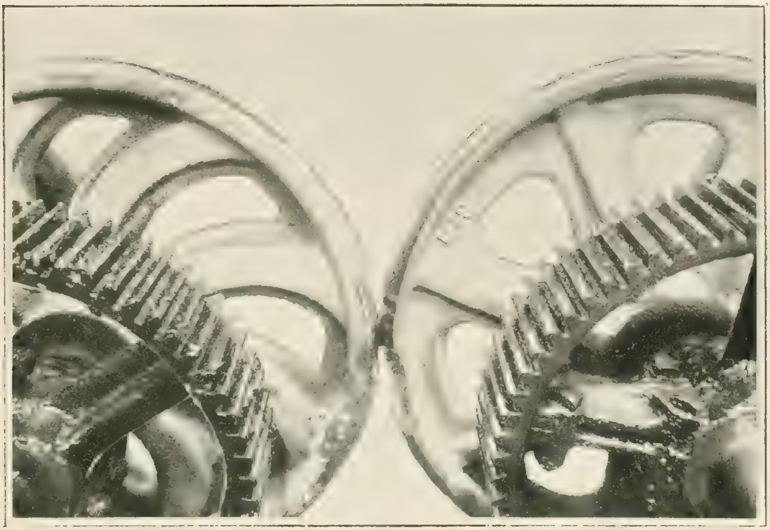
The large "flat" was caused by sliding the car in from the place of accident. This "flat" extends below the "chill" so that grinding will not save the wheel.

In general, cast iron wheels can be used where serious results are not liable to follow a derailment at maximum speed. Where cast iron wheels are used, the inspection of the condition of the flange must be frequent and efficient. Sharp or chipped flanges are dangerous, and flat wheels extremely obnoxious. Flat wheels are caused by skidding the wheels at the stopping, and the condition is aggravated when sand is used. On roads where the weight per wheel is heavy and there are a large number of grades on which stops are made, a large number of flat wheels must be expected. On other roads where conditions are more favorable they rarely occur before the full depth of the chill is worn off the tread. Where flat wheels are common, grinders can be employed on wheels that are not too badly worn. The advisability of grinding a wheel may be well judged by measuring its circumference at the tread. If this is about 2 inches less than when new, the wheel is not worth grinding. Steel tired wheels rarely become flat, but when they occur will usually grind themselves out on the brake shoes. The greatest trouble with steel tires is the wearing of the flanges. This makes it necessary to re-turn the wheels several times during their life, it being most economical to turn them before they are badly worn, as when wear is once started on the flanges it increases very rapidly and if the wear is great it is necessary to turn very deep on the tread in order to form a new flange. Great care must be exercised in obtaining exactly the same circumference of the two wheels of any pair to prevent their crowding one rail or the other, with a consequent destruction of flanges and an increase of train resistance. Where cast iron wheels are used there should be less than ⅛-inch difference in circumference when paired. Some roads have special brake shoes made of a cutting substance, as carborundum or emery, which they fit on the brake shoe of the "flat" wheel.

The gauge of wheels must also be very closely watched. The best method is to use a gauge that comes in contact with the wheel at two points, one on the tread and one about ¼ inch up on the tread side of the flange. This insures a correct gauge independent of the form of the flange which, especially with old wheels, is apt to vary considerably.

In reference to the form of flanges to be used, the best results will be obtained by using the manufacturer's standard for the given class of service. For interurban service where cars run over city tracks, in no case should the flanges be deeper than those used on the city cars, otherwise all the wear on special work, crossings and grooved rails will be done by the interurban wheels. It is better to have a ¾-inch flange in good condition than an 1⅛-inch flange that has been chipped.

Converter Substations. Successful substation operation means careful attention to details. Every part of the apparatus should be looked after with the greatest care so that at a moment's notice the overload capacity of every machine can be thrown on the line. This requires a good smooth commutator with brushes well fitted, brush tension properly adjusted, all contacts well cleaned and breakers properly set. A circuit breaker is made to protect the machines and not to stop traffic, which latter would seem to be their function from the way they are operated on some roads. They should in no case be set to operate at a load less than the rotary converters or the car motors will commutate. There is a case on record where a chief engineer lost his position for the simple reason that the breakers were set below the capacity of the generators and below the current required by the load, with a consequent frequent interruption of service.



CAST IRON CAR WHEELS ON THEIR WAY TO THE SCRAP HEAP

The one on the left was in continual service only six months while its companion ran about a year. Such results may arise from poor castings, or from improper fitting of wheels to track gauge.

It is good policy to change the oil in the converter bearings once in two months, at least. The old oil can be filtered and used on pumps, etc., in the power house. The ends of the armature should be wiped off carefully every day to prevent oil from working its way onto the commutator where it is very injurious to the mica.

The question of synchronizing and compounding rotaries will be taken care of by the construction engineers and their instructions should be carefully followed. In no case should the field adjustment be left to chance. The power factor and the regulation both depend almost entirely on the field adjustment and both have a large influence on the efficiency of the power system. This is explained in a paper by Mr. P. M. Lincoln in the March, 1904, issue of THE ELECTRIC CLUB JOURNAL.

COMMUTATORS AND BRUSHES. On any railway system the proper care of commutators on generators, rotaries, converters and motors is necessary to good results.

Commutator lubricants should be used sparingly, as they not only increase the resistance of the brush contact, but if allowed to accumulate are injurious to the mica. After sanding a commutator, it is well to apply a little compound or oil, all except a very thin film being immediately removed by passing a piece of cheese cloth over the commutator.

Brushes should be ground in place to a perfect fit to the commutator and the contact surface examined frequently to remove any foreign substance, such as copper dust, which is apt to become imbedded in the surface of the carbon and cause sparking.

If the commutator becomes irregular to any perceptible extent, a thin cut should be turned off, as the wear is rapid at low bars and can only be stopped by turning all other parts of the commutator down to the low bars. Pieces of grindstone fitted to the commutator can be used to good advantage to keep a commutator true. On new machines it is well to tighten the commutator before turning.

COMMERCIAL TESTING OF STEAM TURBINES

By A. G. CHRISTY

I ASSUME at the outset that the mechanical construction and the practical operation of steam turbines which have been so ofen described in the technical press have been quite generally read and so shall not discuss these subjects in this paper. However, I believe that the following description of a steam turbine testing plant and its methods of testing will be of interest to engineers and instructive to all students of engineering.

The turbine department is shown in Fig. 1 and Fig. 2. The turbine parts, after being machined, are brought from the main shop by a system of industrial railways, the cylinders and spindles are bladed and the whole engine assembled. A space of about 200 feet in the central part of the department has been built and equipped especially for testing. The visitor is at once impressed with the completeness and permanence of all the construction work and equipment, and the practical and scientific manner in which tests are conducted. In fact, tests are made daily with as much care and accuracy as in the best equipped college laboratory.

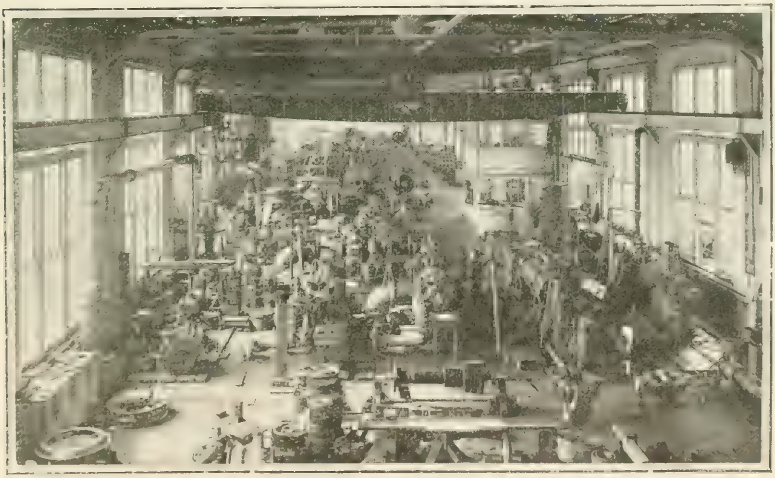


FIG. 1—TURBINE SHOP

A plan of the testing department is shown in Fig. 3. There are two separate and independent testing floors, *A* and *B*, each with its own system of piping, circulating pump, condenser, hot-well pump, weighing tanks, and air pump.

The larger of these test floors, *A*, Fig. 3, has four stone foundations 50 feet long and 5½ feet wide, capped with cast iron surface plates. The pit between these is 6½ feet wide and 8½ feet deep. A tunnel 7 feet wide and as deep as the pit runs along one end and serves for a passage way. Through it are carried the live steam pipes. This testing floor is for engines of 750 kw and larger. The engine bed-plate, which is of the box pattern, bridges one of these pits. Fig. 4 shows a 1250 kw turbine on the test floor. The various exhaust pipes connect with a header, which passes along the ends of the pits and enters the bottom of the condenser by a T-pipe. The hot-well of the condenser is attached to the low arm of the T-pipe. This arrangement allows steam, already condensed in the exhaust line, to pass into the hot-well without having to enter the condenser. The exhaust line is provided with an atmospheric exhaust relief valve, and also with suitable means for completely shutting off any branch leading up the pits. Thus any one engine can be operated and tested with all of the other engines on the floor shut off from the main exhaust line.

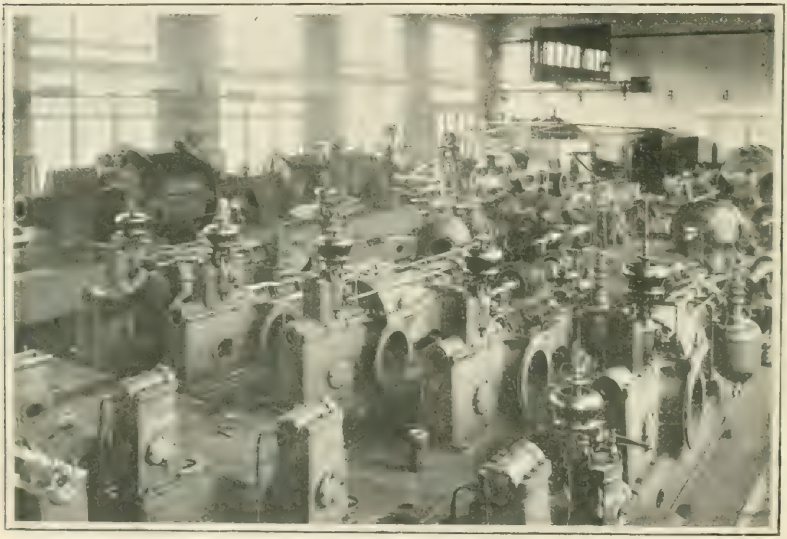


FIG. 2—SEVERAL 400KW ENGINES ASSEMBLED IN BLADING SECTION

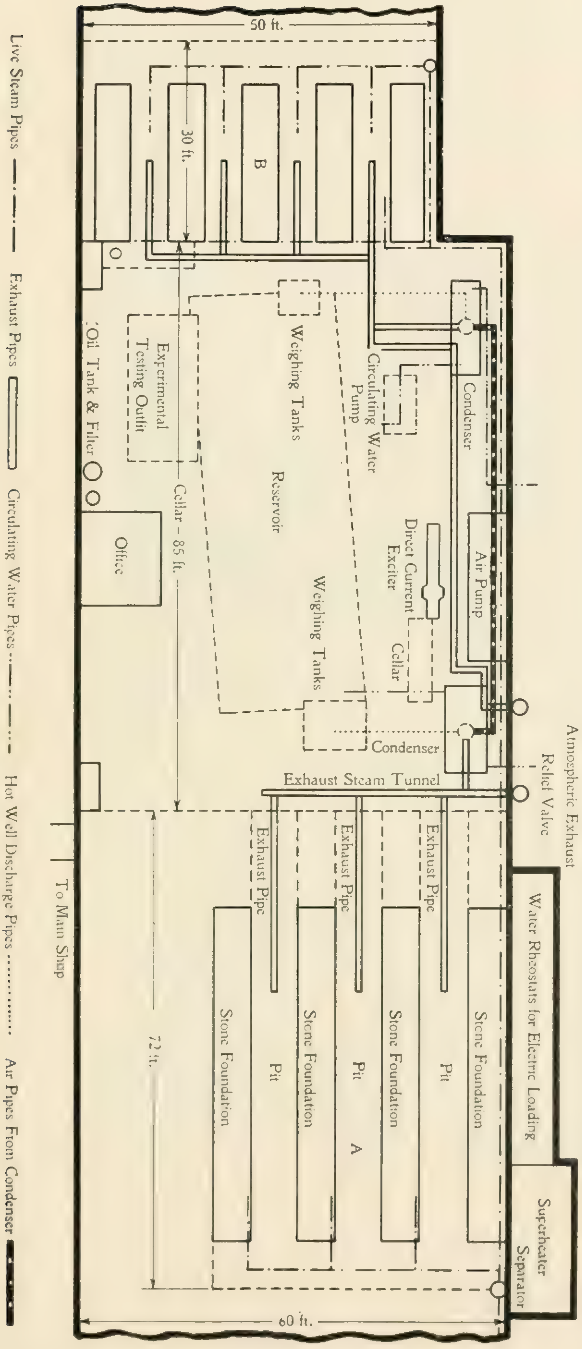


FIG. 3—PLAN OF TESTING DEPARTMENT

A surface condenser of 3,000-horse power serves test floor *A*. An illustration of it and its air pump is shown in Fig. 5. The two air cylinders of the pump are 18 inches in diameter and are fitted with mechanically operated slide valves. The steam cylinder is 8 inches by 24 inches, fitted with Corliss valve gear. The circulating water is supplied by a direct connected 16-inch centrifugal pump, an illustration of which is shown in Fig. 6.

The condensed steam drains from the condenser into the hotwell from which it is pumped into the weighing tanks. By means of a three-way cock, it can be made to discharge into either one of these as required. The weighing tanks, each of 500 gal. capacity, are mounted on scales on a suitable platform as shown in Fig. 7.

Exciting current for the fields of alternating current generators on the test floors is supplied by a 120 kw turbine outfit on the shop floor. An illustration of this is shown in Fig 5.

Steam comes from the boiler house through a 12-inch pipe to the separator, which removes any condensation. Following the separator is a system of valves by which the steam can be passed through the superheater or sent direct to the test floors. The superheater is similar in construction to a Babcock and Wilcox water-tube boiler. It is independently fired with natural gas. Successful tests have been run when the temperature at the superheater outlet was 650 degrees Fahrenheit, which at 150 pounds boiler pressure means a superheat of nearly 300 degrees Fahrenheit.

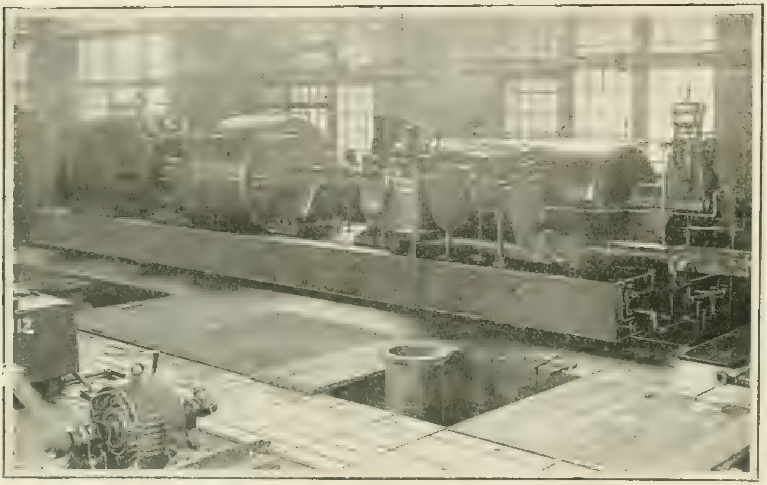


FIG. 4—A 1250KW TURBINE ON THE TESTING FLOOR

In the boiler house are four batteries of Babcock and Wilcox water-tube boilers of 500 horse power each, which with the vertical boilers located over the forge-shop heating furnaces gives a total boiler capacity of 3,000-horse power. The safety valves are set at 160 pounds, which, of course, imposes this limit upon the steam pressure for testing purposes.

The other test floor *B,* Fig. 3, is in general arrangement a duplicate of the one already described, but for engines of smaller size than 750 kw. It has five foundations 25 feet long and $5\frac{1}{2}$ feet wide, of similar construction to those already described. As on the other floor, all engines except the one to be tested can be blanked off from the main exhaust header. As the present type of 400 kw. steam turbine has a very narrow bed-plate and exhausts from one side, it is placed on the foundation instead of bridging the pit, and is connected to the exhaust line by an elbow.

Steam for this test floor is brought from the valves at the superheater, through a 6-inch pipe to the farther end of the floor. This pipe is carried along the wall and is heavily lagged throughout its length of about 220 feet. At the test floor it turns down under the floor and passes along a tunnel at the end of the foundations from which connections are made for each individual engine. A separator, placed on the main line, just as it passes below the floor, removes all condensation.

The condenser for this floor is of the surface type and has a capacity of 1,000-horse power. The air pump for this condenser is piped up in a similar way to the one on the other floor with a separator on the air line. Either pump has sufficient capacity to maintain a 28-inch vacuum on both condensers, with an engine running on the floor.

The circulating water is pumped from the reservoir and discharged into the creek outside. The condensed water is pumped from the hot-well into a smaller set of weighing tanks similar to those previously described. After weighing, all the sets of tanks discharge into the reservoir.

In addition to the two main testing floors, there is a complete outfit for experimental testing. This is provided with its own condenser, air and circulating pumps and weighing tanks.

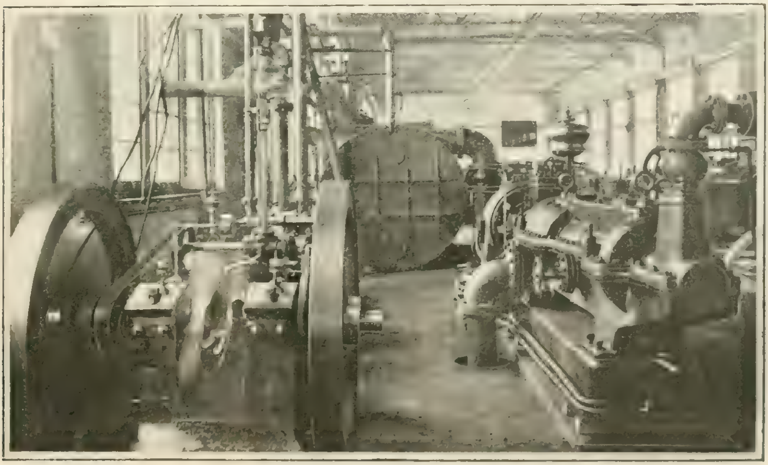


FIG. 5—LARGE CONDENSER, AIR PUMP AND EXCITER TURBINE.

It may be interesting to note that with any one of these condensing outfits tests can be, and have been, made with the engine running non-condensing and without back pressure, and yet condensing all the steam used and weighing it. A simple arrangement allows the air to escape from the condenser without allowing steam to pass out.

A system of supply and return oil pipes connect the large oil tank and filter with both test floors, so that oil can be pumped into an engine from the supply tank or from the engine into the filter.

Whenever possible, brake tests are made on the steam turbines, thereby avoiding the trouble and expense of an electrical test. A water brake, which after numerous experiments with various types has proved the best, is used for these tests. The water brake has been especially developed for turbine testing work and has given highly gratifying results, not only from the standpoint of constancy and accuracy of loading, but from ease of manipulation and freedom from the necessity of attention.

These brakes are very powerful. One small brake used for testing 400 kw engines, running at 3,600 r. p. m., has carried 1,200 brake horse power, and others have been used up to 2,500-horse power. The load can be changed almost instantly by simply regulating the water supply by a small hand valve. The oiling of the brake bearings is done by the turbine oil pump, and hence is automatic after the engine is up to speed.

To show the speed of the turbine at any instant, a tachometer of standard centrifugal type for high speeds is belted to the turbine or generator shaft at some suitable point. A Veeder tachometer, using alcohol, is also included in the test-floor equipment and gives even more accurate readings than the centrifugal tachometer. When an engine is carrying a given load for a certain interval of time and the speed—constant so long as the load is constant—is to be accur-

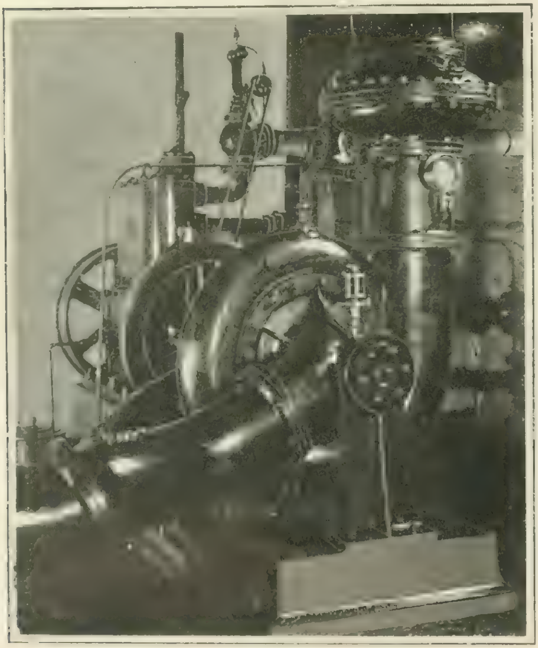


FIG. 6—CIRCULATING PUMP

ately taken during that interval, a continuous counter is attached to some part of the governor case so as to register the number of strokes the oil pump makes. The oil pump being directly driven by a worm and worm-wheel, and eccentric from the turbine spindle, the speed of the turbine spindle can be readily calculated.

For tests not using superheat, a throttling calorimeter is used to determine the quality of the steam. These are carefully lagged, and can have their exhaust so regulated as to give in all tests a constant absolute back pressure of 18 pounds in the calorimeter as shown by an attached mercury column. These calorimeters give very accurate results, being checked by a thermometer placed in the steam line beside the calorimeter which indicates the temperature of the steam the moment it arrives at the throttle.

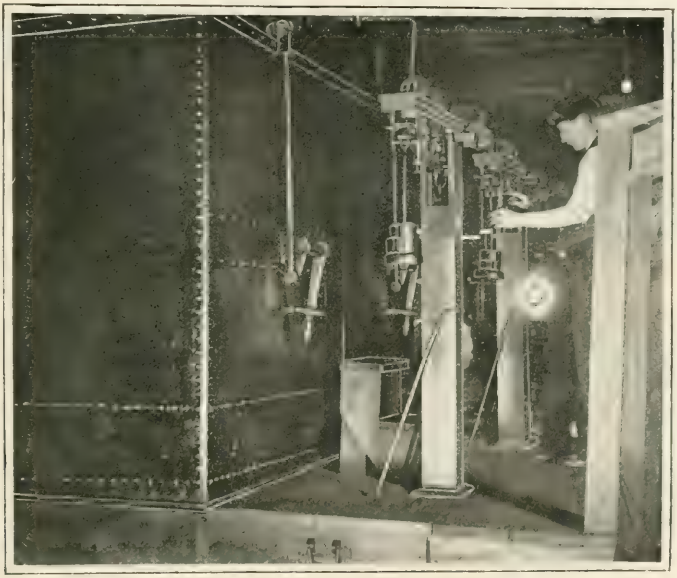


FIG 7—WEIGHING CONDENSED STEAM FROM THE TURBINE TEST

On account of the distance from the boilers, the superheater is used when dry saturated steam tests are to be made, enough heat being supplied to give dry steam at the calorimeter. Each individual test floor is supplied with a calorimeter permanently attached to the steam supply line.

When tests with superheat are made, a thermometer placed in a mercury cup fitted in the top of the steam strainer gives the temperature of the steam as it arrives at the throttle.

Usually only two sizes of gauges are used, i. e., those reading to 160 pounds and compound gauges reading to 30 pounds pressure and 30 inches vacuum.

The vacuum is measured by a mercury column with carefully graduated and plainly marked scale. This is mounted in a suitable case and on a firm stand. It can thus be moved around the shop without fear of breakage, and can be connected to any exhaust by ¼-inch pipes provided for this purpose.

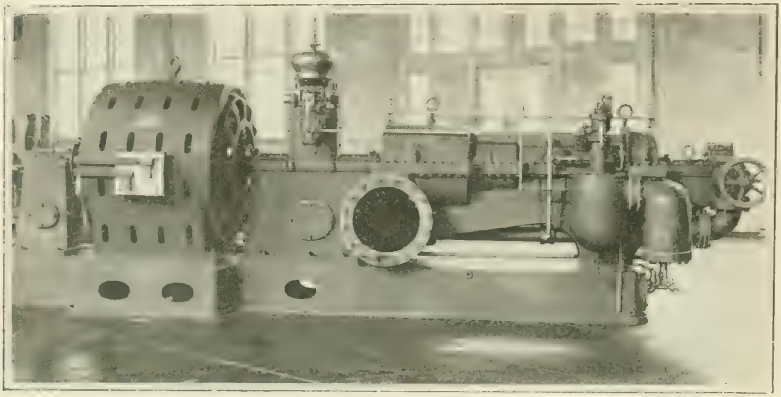


FIG. 8—A 400KW TURBO-GENERATOR SET

The vacuum can be regulated to almost any desired degree. The exhaust lines have been so well connected up that a vacuum of 29⅝ inches has been carried at the exhaust of an engine with a barometer of only 29¾ inches. Lower vacuums are obtained by reducing the supply of circulating water for the condenser until the mercury stands about ½ inch above the required height. It is then regulated by allowing air to leak through an adjustable opening into the exhaust line. On the small condenser it is not necessary to adjust the circulating water supply, as the adjustable air leak alone can control the vacuum.

A barometer kept in the foreman's office has a very carefully made scale and, by a Vernier attachment, will give readings to 1-100 of an inch.

When electrical tests are made, it is essential, with alternating current, that the load shall be non-inductive. To provide such a load, a water rheostat is used, consisting of three wooden tanks about 10 feet long by 3 feet wide and 3 feet deep, of about 1,500 gallons capacity, placed in a small addition to the main shop. These are filled with water and have iron electrode plates inserted, the number of plates required to be used in a given test being determined by the current to be carried. The terminals of the generators are connected to these plates by cables. After the water becomes thoroughly heated to constant temperature by passing current through it, any load can be regulated by the spacing of the plates. Sometimes with low voltages and heavy currents salt has to be added to the tanks to reduce the resistance in order to secure the load desired.

Before any tests are made, all apparatus is carefully calibrated. The steam gauges are tested by a Crosby Gauge Tester. Gauges are generally calibrated both before and after the test in order that errors due to overheating or other causes during the tests may be accounted for. Thermometers are usually calibrated in their respective mercury cups on the engine after the engine is started, but before the test is begun, so as to have a current of steam about them. A steam gauge which has been already calibrated is attached beside the thermometer cup. A series of simultaneous readings of gauge and thermometer is made. The readings of the gauge are corrected to standard. The barometer is noted, and from a set of steam tables the theoretical temperature is found. From these readings an average correction is found for the thermometer readings.

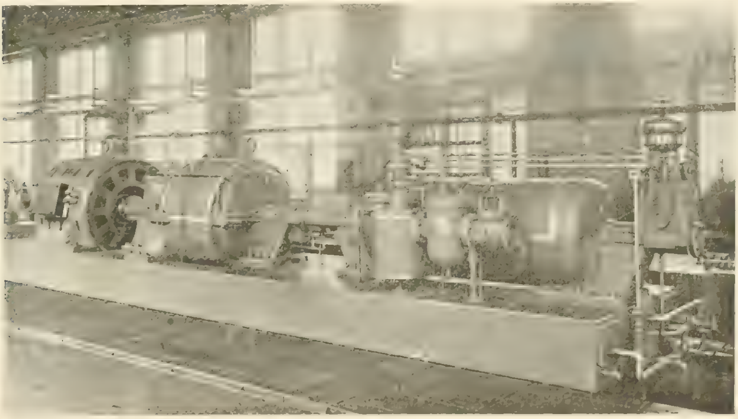


FIG. 9—A 1500KW TURBO-GENERATOR SET ON THE TESTING FLOOR

Suppose now the steam turbine to be tested is already assembled on the test floor, all adjustments made and the generator or water brake connected up. A preliminary run is made to see that all parts are free and in running order. During this run the thermometers are calibrated. Then the load is put on for the governor test. With a water brake the load can be obtained in a few seconds.

but with a generator much time is taken in heating tanks, adjusting plates, etc. In fact, generator tests are now rarely made. Full load is put on and minute readings for five minutes are taken on the continuous counter. Also, minute readings of load are made. The conditions for the five minutes, i. e., the steam pressure at the throttle and at the high pressure inlet, and the vacuum are noted. Between full load and no load a number of loads are taken that will give sufficient points for a good curve and these readings are all taken for each load. Then from the readings of the continuous counter the speed is calculated and a load-speed curve drawn. From this curve the total governor variation is found as well as the governor regulation over different loads. This curve is very useful after the engines are installed, especially if they are to run parallel with other engines.

The next step in large engines is to set the small centrifugal governor that controls the automatic throttle. This is usually set so that with a 10 percent increase in speed it will shut the engine down.

When an automatic secondary valve is provided, load is added and the valve set to open at the required pressure.

The steam turbine is now ready for economy tests. The purchaser wishes to have tests of his engines made with conditions as near as possible to those it will operate under, i. e., same boiler pressure, superheat, if any, and vacuum. This particular turbine testing plant, by the flexible arrangement of its apparatus, can supply all these conditions except boiler pressure where this exceeds 160 pounds, the limit of the boilers in use. Each engine then is tested under a given set of conditions as specified in the contract of sale. The vacuum is usually stated as so many inches of mercury referred to a 30-inch barometer. As the barometer at Pittsburg is never up to 30 inches, the vacuum as shown by the mercury column attached to the exhaust must be corrected to the observed barometer.

Tests are usually one hour runs. On the brake, readings are taken every minute. The condensed steam weights are taken either every five or ten minutes according to quantity. All other readings are recorded at the start of the hour and every five minutes thereafter. What is known as "high-pressure-inlet pressure," is the average pressure of the steam, as shown by a gauge, after it has passed through the poppet valve and before it enters the blades. This pressure varies with the load. The speed is either held at the rated speed for all tests, or the governor set to give the rated speed at

PRESSURE AND TEMPERATURE READINGS

Time	Throttle Pressure	H. P. Inlet Pressure	Vacuum by Mercury Column	Temperature of Throttle	Continuous Counter
11:25 A. M.	148	115	27.6''	494	641235
11:30	148	117	27.6	496	642075
11:35	154	120	27.6	498	642916
11:40	152	120	27.6	498	643760
11:45	149	120	27.6	498	644605
11:50	145	120	27.6	498	645445
11:55	154	120	27.6	499	646285
12:00 M.	154	120	27.6	499	647131
12:05 P. M.	147	120	27.6	500	647974
12:10	150	120	27.6	501	648813
12:15	155	115	27.6	502	649655
12:20	149	115	27.6	501	650500
12:25	153	115	27.6	500	651342
	1958	1537		6484	Difference 10107
Average	150.6	118.2	27.6	498.8	168.45
Calibrations	+0.0	- 1.0	....	+6.0	21:1
Corrected readings	150 6	119.2	27.6	504.8	3537.5 r. p. m.

Superheat at throttle 138.9°. Barometer 29.6 in.

BRAKE READINGS

Brake No. 3; Brake Radius, $20\frac{3}{32}$ Inches; Dead Weight, 32 Lbs.; Nominal Load During Test, 585 hp.

Time A. M.	Gross Scale Weight	Time A. M.	Gross Scale Weight	Time A. M.	Gross Scale Weight	Time P. M.	Gross Scale Weight	Time P. M.	Gross Scale Weight	Total Gross Scale Weight
11:25	585	11:38	580	11:51	590	12:02	578	12:15	575	....
11:26	581	11:39	580	11:52	588	12:03	576	12:16	575	....
11:27	575	11:40	578	11:53	587	12:04	586	12:17	577	....
11:28	582	11:41	581	11:54	592	12:05	595	12:18	586	....
11:29	585	11:42	572	11:55	585	12:06	593	12:19	590	....
11:30	586	11:43	583	11:56	595	12:07	598	12:20	590	....
11:31	585	11:44	588	11:57	591	12:08	600	12:21	588	....
11:32	584	11:45	594	11:58	574	12:09	597	12:22	585	....
11:33	582	11:46	585	11:59	586	12:10	595	12:23	581	....
11:34	585	11:47	587	M.		12:11	590	12:24	585	....
11:35	584	11:48	587	12:00	582	12:12	585	12:25	585	....
11:36	581	11:49	588	P. M.		12:13	586	....	....	....
11:37	583	11:50	590	12:01	579	12:14	585	....	....	....
	7578		7593		6449		7664		6417	35701

Horse power, 624.15.

Average gross weight, ... 585.2 lbs.
Dead weight, ... —32.0 lbs.

Net weight, ... 553.2 lbs.

some given load and the speed allowed to vary for other loads, as shown by the governor curve.

For condensed water, a gauge glass has been placed on the hot-well so as to indicate the height of the water inside. The dead weight of one of the weighing tanks is taken before the test starts. On the second for starting the test, the three-way cock is thrown to allow the water to run into the set tank only, and at the same time an indicator is set at the level of the water in the gauge glass in the hot-well. The dead weight of the other tank is taken and at the end of five minutes the water is turned into it. The total weight of the first is then found, and by subtracting the dead weight the net condenser discharge for five minutes is found. At the end of the hour the height of water above or below the indicator on the hot-well gauge glass is noted and a correction for the weight of the water that has been pumped out, or should be pumped out, is made to the net weight of condenser discharge for the hour. After an engine has been tested, the main exhaust line is completely blanked off from all engines; water is circulated through the condenser and a vacuum carried by the air pump equal to that called for in the test. Any leakage in the condenser tubes collects in the hot-well and is pumped over and weighed. This is known as "condenser leakage," and as a correction it must be subtracted from the net condenser discharge.

The leakage through the water glands into the vacuum ends of the cylinder is measured by a special set of weighing tanks, and also deducted from the net condenser discharge.

After all corrections have been made to the net condenser discharge, the remainder will be the actual weight of condensed steam required by the engine to carry the given load for one hour under the given conditions.

On 400 kw turbines usually only three tests are made, one a little over full load, another at three-quarter load and a third at slightly less than one-half load. On the larger engines four is the usual number of tests; one at 50 percent overload, a second at full load, a third between one-half and three-quarter load and a fourth at one-quarter load.

After the tests have been made, the readings are corrected and worked up. The first step is to write up, in suitable blanks, copies of all calibrations and from these the corrections for each instrument or thermometer are found. The readings of pressure and temperature are averaged and corrected from the calibrations. For the

GLAND LEAKAGE

Time	Weight of Tank, Lbs.	Leakage of Glands
11:25 A. M.	465	235
11:40	230	
11:40	486	243
11:55	243	
11:55	470	240
12:10 P. M.	230	
12:10	455	235
12:25	220	

Total leakage, 953.
Gland leakage per hour, 953.

WEIGHTS OF CONDENSED STEAM

Time	Dead Weight	Gross Weight	Net Weight
A. M.			
11:25	....	....	....
11:35	1109	2502	1393
11:45	1128	2524	1396
11:55	1110	2514	1404
P. M.			
12:05	1129	2546	1417
12:15	1110	2518	1408
12:25	1129	2525	1396

Water level in hot well 2½ inches below point at commencement of test.

Diameter of hot well 24 inches.

Net lbs. steam condensed per hour, 7368.

Total condenser discharge per hour,	8414 lbs.
Hot well correction, ...	—41 lbs.
Gland leakage, ...	—953 lbs.
Condenser leakage, ...	—52 lbs.
	7368 lbs.

SUPERHEATER READINGS

Time	Boiler Pressure	Temp. at Superheater Outlet,°F.	Superheat at Superheater Outlet,°F.
A. M.			
11:25	151	604	....
11:30	150	602	....
11:35	160	600	....
11:40	157	600	....
11:45	154	600	....
11:50	147.5	602	....
11:55	156	599	....
12:00	158	600	....
P. M.			
12:05	152.5	604	....
12:10	151	608	....
12:15	159	601	....
12:20	153.5	599	....
12:25	155	597	....
	2004.5	7816	....
	154.2	601.2	....
	0	—6	....
	154.2	595.2	227.5

SUMMARY OF TEST

Time	
From 11:25 A. M. to 12:25 P. M.	
Throttle Pressure Lbs. Gauge per Sq. In.	150.6
High Pressure Inlet Pressure Lbs. Gauge per Sq In..................	119.2
Vacuum in L. P. Outlet by Mercury Column........................	27.6
Vacuum referred to 30″ Barometer	28.
Barometer..............................	29.6
Temperature at Superheater Outlet °F................................	595.2
Superheat at Superheater, °F........	227.5
Temperature at Throttle,°F	504.8
Superheat at Throttle, °F...........	138.9
Quality shown by Calorimeter......	....
Speed shown by Continuous Counter	3537.5
Load in Brake Horse Power........	624.15
Load in Kilowatts....................	....
Load in Electrical Horse Power.....	....
Total Net Lbs. Steam Condensed..	7368.
Lbs. Steam per B. H. P. Hour...	11.80
Lbs. Steam per E. H. P. Hour (calculated from gen. eff.)......	12.82
Lbs. Steam per I. H. P. Hour (calculated)........................	10.03

corrected boiler pressure and the corrected temperature at the superheater outlet we can find, with a set of steam tables, the superheat at the superheater outlet. From the throttle pressure and temperature we can find the superheat at the throttle, if any. From the calorimeter the quality of steam can be ascertained. It is customary only to obtain the superheat and quality from the averages for the hour, though sometimes on special tests these are figured for every five minutes. The average speed of the engine can be found from the reading of the continuous counter or the counted strokes.

If a generator has been used, the electrical readings are averaged and corrected for calibrations and the load calculated. Similarly brake readings are averaged, the dead weight subtracted and the load calculated. The total steam consumption is found directly from the condensed steam.

Then from the results of a set of tests a steam consumption curve is drawn whose co-ordinates are load and total pounds of condensed steam per hour, and from this another curve whose co-ordinates are load and pounds of steam per horse-power per hour. Such a set of curves has been printed in the March issue of THE ELECTRIC CLUB JOURNAL, page 91.

It may be interesting to note some results from an original set of readings for one of the official tests of a 400 kw steam turbine now installed at the works of the Sherwin-Williams Company, at Cleveland, Ohio. These are given in the accompanying tables. The results show the remarkably low steam consumption of even this small size of steam turbine. To compare with reciprocating engines, it is necessary to transfer this rate into pounds for indicated horse power. Assuming, as is the usual practice, that the mechanical efficiency of the water-brake and steam turbine combined is the eighty-five percent, the steam consumption becomes 10.03 pounds per indicated horse-power per hour. This is more than a favorable comparison with any reciprocating engine yet built.

The testing equipment, which is described in this article, is that of the Westinghouse Machine Company, of Pittsburg, Pa.

THREE-PHASE TRANSFORMATION

By J. S. PECK

TO transform from one three-phase circuit to a second three-phase circuit either of several arrangements of transformers may be employed as follows:

(1.) Three single-phase transformers connected in delta or in star.

(2.) Two single-phase transformers connected in *V* or in *T*.

(3.) One three-phase transformer with windings connected in delta or in star.

As the transformers required in either of the foregoing arrangements may be placed in one frame or case with three primary and three secondary terminals, the unit may be termed a three-phase transformer in a general sense. In so far as their practical use is concerned, the three arrangements are essentially the same.

If, however, the magnetic and electrical characteristics of the transformers be taken into account there are marked differences between the several methods. For three-phase transformation it is essential that there shall be magnetic fluxes of two or three different phases. When three single-phase transformers are used the magnetic fluxes in the several transformers differ in phase by 120 degrees respectively. When two single-phase transformers are used the magnetic fluxes in them differ by 120 degrees or by 90 degrees according to the method of connection. In the true three-phase transformer there are three magnetic fluxes differing in phase, but these fluxes are not limited to separate and independent cores as in the foregoing arrangements. In the three-phase transformer certain portions of the iron core carry the fluxes of two or of all three of the magnetic circuits. As the resultant of two or three magnetic fluxes which are out of phase with one another is less than their arithmetical sum, it follows that there is a certain economy in material in so arranging the magnetic circuits that certain parts of the iron carry the magnetic fluxes of more than one of the magnetic circuits. There are also in certain cases other economies in building a single three-phase transformer instead of using two or three smaller transformers for the same aggregate output.

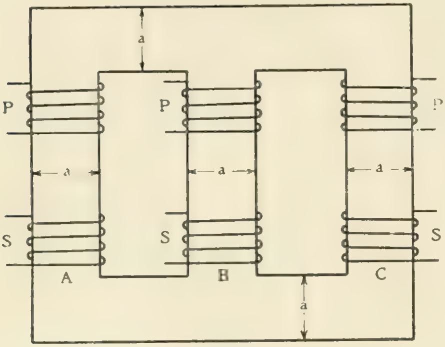


FIG. 1

In construction the three-phase transformer follows one of the two general forms in common use for a single-phase transformer and may be either of the core or shell type. The general appearance of the most common forms of three-phase transformers of these two types is shown in Figs. 1 and 2.

CORE TYPE

Consider first the core type of the form shown in Fig. 1. It will be seen that there are three cores of equal cross-section joined by a common top and bottom yoke of the same section as each core, and that upon each core are placed the primary and secondary windings for one phase. The coils on the three cores are connected so that the fluxes in the cores are 120 degrees apart, making their algebraic sum zero at any instant. The relation of the fluxes is shown in Fig. 3, which indicates that there is 120 degrees difference between the time that the flux in *A* is a maximum in one direction, until that in *B* or in *C* becomes a maximum in the same direction, and it will be seen that when the flux in *A* is a maximum in one direction, it is balanced by fluxes in *B* and *C* in the opposite direction. As in a three-phase transmission system three wires are sufficient for carrying the three-phase currents, so in a three-phase transformer three cores are sufficient for carrying the three-phase fluxes.

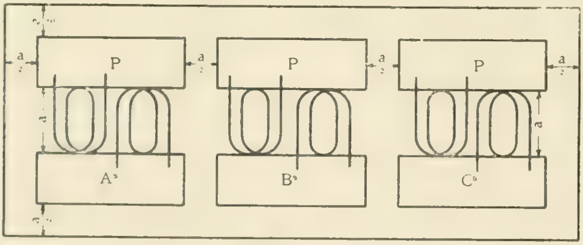


FIG. 2

In a three-phase transmission system, it is customary to arrange the three wires in the form of an equilateral triangle, for with this arrangement the mutual induction between any two circuits is the same, but for the sake of simplicity, the three wires are often placed in the same line; similarly, in a three-phase transformer, when the mutual magnetic relations between the three phases are to be identical, the three cores are arranged in triangular form. But it is found that by properly proportioning the transformer, the three cores may be placed in the same line with but an insignificant departure from symmetrical relations, and as this arrangement gives a better and cheaper mechanical construction, it is the one usually adopted.

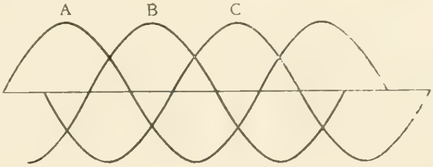


FIG. 3

With the core transformer shown in Fig. 1, it is evident that a short-circuit in any phase will render the whole transformer inoperative for transforming three-phase currents, as the resultant flux from the two operating phases will be driven through the short-circuited coils, and cause an excessive current to flow in the windings. The transformer may, however, when one phase is short-circuited, be operated single-phase, by connecting the two undamaged phases as would be done if the short-circuited coil were removed. With one phase open-circuited, the two remaining phases may be reconnected in *V* or in *T* for transforming from three-phase to three-phase; or the windings may be connected in series or parallel for single-phase transformation.

On small transformers the cost per kilowatt decreases rapidly and the efficiency increases rapidly, with increase in size.

The reduced first cost and the improved efficiency of a three-phase core-type transformer of the form shown in Fig. 1 over three single-phase transformers, or over two single-phase transformers, may be illustrated as follows—where it is desired to transform three kilowatts from three-phase to three-phase.

In Fig. 4 a two-kilowatt single-phase transformer is shown with each leg wound for one kilowatt. If to this be added a third leg, shown by dotted lines also wound for one kilowatt, there will result a three-phase three-kilowatt transformer, which has been obtained with an increase of material of almost exactly 50 percent over that required for one two-kilowatt single-phase transformer and which has an efficiency approximately equal to that of the two kilowatt single-phase transformers.

The cost of transformers for making the above transformation may be expressed as follows:

(1.) By three transformers connected in delta or star—three times cost of one 1-kw transformer.

(2.) By two transformers connected in *V* or *T*—two times cost of one 1½-kw transformer.

(3.) By one three-phase transformer—one and one-half times cost of one 2-kw transformer.

Since a 2-kw unit costs less per kilowatt and has a higher efficiency than the 1 or 1½-kw unit, it is evident that the three-phase unit will cost less and be more efficient than either of the other combinations. There is also a slight additional gain in cost on this type due to the fact that a single case or housing is required, though it is of course possible to place two or three single-phase transformers in the same case. It should, however, be borne in mind that a three-phase transformer will never be so cheap or so efficient as a single-phase transformer designed along the same lines and wound for the same total output.

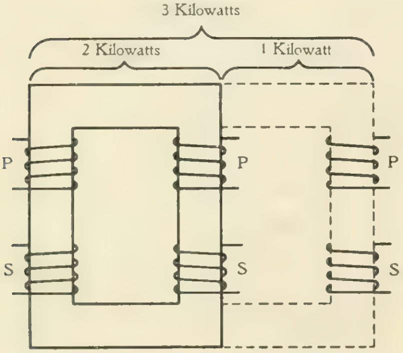


FIG. 4

The relative advantages and disadvantages of the core-type, three-phase transformer as compared with groups of single-phase transformers may be summed up as follows:

Advantages of Core-type Three-phase Transformer—

(1.)—Reduced cost and higher efficiency.

(2.)—Ease in handling (Does not apply to large units).

(3.)—Reduced floor space.

(4.)—Simplification of leads and connections.

Disadvantages of Core-type Three-phase Transformer—

(1.)—Loss of any phase disables the whole transformer, whereas with three single-phase transformers in delta, one may be disabled and the two remaining ones used to change from three-phase to three-phase.

(2.)—Unequal loads may give unequal voltages on the three phases.

(3.)—Increased cost of spare unit.

(4.)—Trouble in one phase may damage the other phases.

(5.)—Increased cost of repairs due to the fact that the whole transformer must be dismantled, and in case of returning it to the manufacturer, the freight charges are increased over those which would be incurred with a single-phase transformer.

In order to obtain a three-phase core-type transformer, which will not be entirely disabled when one phase is short-circuited and in which the unbalancing in voltage produced by unequal loads on the three phases will be eliminated, various modifications of the construction shown in Fig. 1 have been proposed. One of these is shown in Fig. 5. It will be noted that it consists of three single-phase transformers, placed one above the other with the section of core between two openings equal to that at all other parts of the circuits. This equal section for the part common to the fluxes of two phases is possible on account of the fact that these fluxes are 120 degrees apart, with a resultant equal in amount to one of them.

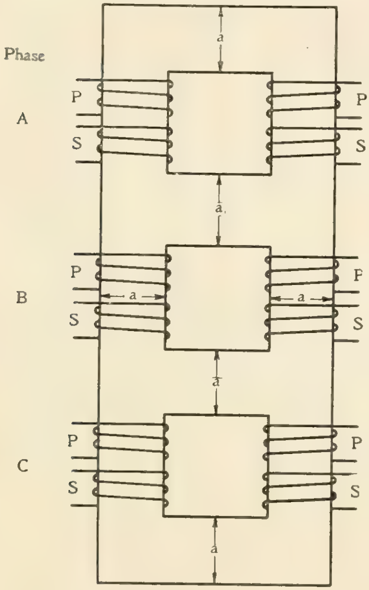


FIG. 5

Comparing this transformer with three single-phase transformers, it will be noticed that the only gain is that due to a slight saving in the amount of material required for the iron core, possible on account of the reduced section in that part of the magnetic circuit common to two phases. But this saving is insignificant in comparison with the total cost of the transformer; and to offset this gain there is a loss due to its more difficult mechanical construction, as well as to the extra provisions which must be made for the cooling of the three transformers placed one above the other.

SHELL TYPE

For units of small size, the core type of construction is well adapted; but for larger units, the shell type of construction possesses many advantages both electrical and mechanical. It is for this reason used for three-phase transformers of large size.

The most common form is that shown in Fig. 2, which consists essentially of three single-phase transformers placed side by side, as shown in Fig. 6, with the section between the openings of two phases reduced from *a* with the single-phase transformers, to ½ *a* with the three-phase transformer. This reduction in section is made possible by the fact that the windings of the different phases are so connected that the fluxes in that portion of the magnetic circuit common to two phases are 120 degrees apart, so that their resultant is equal to one of them. In this respect, it will be noted that the shell-type transformer is similar to the core-type of construction shown in Fig. 1.

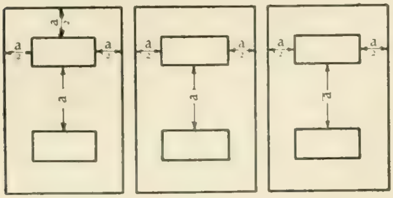


FIG. 6

This reduction in the amount of iron required for the magnetic circuit amounts in general to from ten to twenty percent of the total iron in the transformer, and as the iron is but one of a large number of items which enter into the cost, the total saving over three single-phase units is very small. The actual saving in iron is, however, not so great as would at first glance appear, for when the three cores are combined into one, the internal cooling of the transformer becomes more difficult, and the larger ventilating ducts and clearances practically offset the gain made by the common core. There is, however, a substantial saving in cost resulting from the use of one case instead of three, but this disappears if three single-phase transformers are mounted in one case.

In general, the objections to the use of a three-phase core-type transformer enumerated above apply also to the shell-type transformer, while the advantages of less cost and higher efficiency for the three-phase core-type practically disappear in the case of the three-phase shell-type, leaving reduced floor space and simplicity of connections as the only advantages which may be urged in favor of this three-phase transformer.

It will seem that with the three-limbed core transformer there is a very substantial saving in cost over three single-phase core-type transformers, but that with the core-type transformer shown in Fig. 5 the saving is extremely small. Similarly with the three-phase shell-type transformer, the reduction in cost is almost insignificant.

DUPLEX TRANSFORMER

It has been shown above that the shell-type transformer of a certain size consists essentially of three single-phase transformers, each having one-third the aggregate capacity. The cost of the three-phase transformer is therefore practically three times the cost of one single-phase transformer, except for a slight reduction due to the use of one case instead of three cases. It is possible, however, to use two transformers for changing from three-phase to three-phase, each transformer having a capacity but slightly greater than one-half that of the total amount of power to be transformed. The cost per kilowatt of these units will be considerably less than that of the smaller units. If the two transformers be placed in a single case, there will result a very substantial saving in cost over three single-phase transformers or over one three-phase transformer. It has been proposed to call such a combination a "Duplex Transformer." Its advantage over the three-phase shell-type transformer is that its cost is less and that the two units may be made detachable, so that one can be repaired while the other is in use, or one can be returned to the manufacturer with less cost and inconvenience than would be the case with a three-phase transformer. The objection to the duplex transformer is that there is a tendency for a slight difference in voltage between the three phases when supplying load. By designing the transformer with this point in mind, however, the unbalancing may be reduced to an almost negligible value. It need not exceed that found in two-phase-three-phase combinations, which are now very extensively used, and where the difference in the voltages is seldom even known by the operators.

CONCLUSIONS

(1) Where it is desired to transform from three-phase to three-phase for supplying small motors, rotary converters, etc., the three-phase core-type transformer is cheaper, more efficient, and more compact than a group of two or three single-phase transformers. There are, however, objections to its use, which under certain conditions may offset the advantage which it offers.

(2) Any three-phase transformer, which is made up of three single-phase units joined together by a common core, presents but little gain in cost, efficiency, or compactness, over three separate single-phase units, while there are several distinct objections to its use.

(3) For large three-phase units, the shell-type construction is commonly employed and, since this consists of three single-phase units with a common core, it has few advantages and several disadvantages over a group of three single-phase transformers.

(4) The few advantages claimed for the three-phase shell type transformer, over a group of three single-phase transformers, are: slightly reduced cost, reduced floor space, and simplification of connections. The duplex transformer (two single-phase transformers connected in T and mounted in the same case) is a cheaper arrangement than the three-phase transformer, requires slightly less floor space and its connections are just as simple.

(5) No three-phase transformer, or group of single-phase transformers can be as cheap, efficient, or compact as a single-phase transformer having the same aggregate output; thus the economical use of the three-phase transformer is practically limited to that of supplying three-phase motors and rotary converters, while the single-phase transformer can almost always be used to better advantage for lighting work.

ALBERT SCHMID

Director-General of the Société Anonyme Westinghouse, Havre and Paris

By H. C. EBERT

MR. GEORGE WESTINGHOUSE'S prescience in choosing young men for his assistants in the development of his great workshops has rarely been more clearly exemplified than in the case of Mr. Albert Schmid, who, while in the employ of the French Westinghouse Air Brake Company, in 1885, was personally selected by Mr. Westinghouse to come to the United States for work with his American brake company.

Mr. Schmid began his work in this country as a draftsman with The Westinghouse Air Brake Company, then located in Allegheny, Pennsylvania. Here his keen mechanical perception and his cleverness in putting ideas upon the drawing board brought rapid advancement, and when the Union Switch & Signal Company began its line of electrical development Mr. Schmid was employed as chief designer and engineer. Later on, at the formation of the Westinghouse Electric Company, in 1886, he was chosen to co-operate with the electrical engineers in working out the now well-known mechanical designs of the Westinghouse machines.

Mr. Schmid, who possessed the faculty of rapidly absorbing knowledge from others, as well as from his own experiences, quickly acquired the necessary electrical knowledge and was soon ably qualified to direct the new electric works. He was advanced to the position of Superintendent, and during the tremendous growth of the business of the Electric Company, then located in the old Pittsburg works, Mr. Schmid's most distinguished work was originated. Here, it will be remembered, that the then famously large lighting generators for the Chicago World's Fair and the original 5,000-horse power Niagara Falls Power Company machines were designed and built under his direction.

In this period of early development, Mr. Schmid placed his characteristic stamp on all the apparatus manufactured by this company. The general constructional features then initiated are largely retained at the present time; many of them have been universally adopted.

Upon the removal of the Electric Company's works to East Pittsburg, Mr. Schmid was appointed General Superintendent in charge of all designing and general engineering. In 1897 he made a tour of Europe for the purpose of studying manufacturing possibilities, and as the outcome of this investigation the French Westinghouse Company was formed and Mr. Schmid was made its Director General. Mr. Schmid was admirably suited for this position, which involved meeting the special conditions required for competition with the very different product turned out by the European manufacturers.

Mr. Schmid has succeeded in surrounding himself with a very capable corps of assistants of French and American training. Keenly appreciative of the almost unlimited possibilities of electrical development, he is constantly on the qui vive for improvements in manufacturing economy and the extension of the application of electrical operation to the workships and transportation fields of his territory.

In addition to his work with electrical apparatus, Mr. Schmid took up a number of years ago a study of the design of the gas engine, and as the result a basis was laid in designs and in patents for what has now become an important department of The Westinghouse Machine Company. During recent years he has continued his experimental study of the gas engine as applied to automobiles and has perfected an excellent type of gasoline automobile.

The successful career of Mr. Schmid has been wrought during his young manhood, he having been born in 1857 in Zurich, where he received his technical education.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

A Series of Lectures Delivered before THE ELECTRIC CLUB.

IV—TRANSFORMERS—CONTINUED

By V. KARAPETOFF

(4) *Approximate Practical Diagram*—In practice the diagram in Fig. 32 (see June issue) is usually applied to a transformer under considerable load, so that the magnetizing current *O M* may be readily neglected as compared with the load current. In this case, the condition $i_1 n_1 = i_2 n_2$ is fulfilled, and the currents fall in the same line. The diagram then takes the form shown in Fig. 33.

From a practical standpoint, only terminal voltages $O D_1$ and $O D_2$ are of importance, but not the induced e.m.f.'s $O B_1$ and $O B_2$,

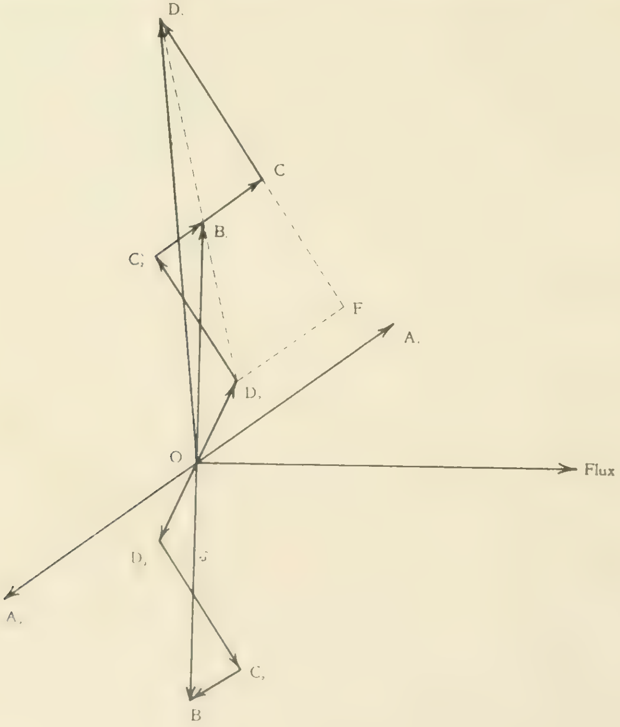


FIG. 33

which cannot be determined experimentally. They can be eliminated from the diagram. To this end, reduce all the secondary voltages in ratio of number of turns $\frac{n_1}{n_2}$ so as to make $O\ B_1 = O\ B_2$ (Fig. 33) and turn the figure $O\ D_2\ C_2\ B_2$ to a new position $O\ B_1\ C'_2\ D'_2$. Now we see that the total drop or regulation of a transformer can be represented by a single triangle $D'_2\ F\ D_1$. On this triangle $D'_2\ F$ is the total ohmic drop and $F\ D_1$ the total inductive drop in the transformer. We may now calculate the lengths $D'_2\ F$ and $F\ D_1$: .

$$D'_2\ F = C'_2\ B_1 + B_1\ C_1$$

but, $B_1\ C_1 = i_1\ r_1$ and $B_1\ C'_2 = r_2\ i_1 \frac{n_1}{n_2} = r_2\ i_1 \left\{\frac{n_1}{n_2}\right\}^2$

hence, $D'_2\ F = i_1 \left\{ r_1 + r_2 \left(\frac{n_1}{n_2}\right)^2 \right\}$.

Resistance $r_1 + r_2 \left(\frac{n_1}{n_2}\right)^2$ can be called the *equivalent ohmic resistance* of the transformer reduced to the primary circuit.

Likewise, we find $F\ D_1 = i_1 \left\{ x_1 + x_2 \left(\frac{n_1}{n_2}\right)^2 \right\}$ where the expression $x_1 + x_2 \left(\frac{n_1}{n_2}\right)^2$ can be called the *equivalent inductive resistance.*

Having constructed this triangle $D'_2\ F\ D_1$ in its proper position, the *actual drop* will be the difference between $O\ D_1$ and $O\ D'_2$ or $D_1\ K$.

An example may make this clearer.

Let us consider a transformer with the following characteristics:

	PRIMARY	SECONDARY
Voltage at no load,	1,000 volts	100 volts
Ohmic resistance	1.3 ohms	0.0125 ohms
Inductive resistance,	6.5 ohms	0.062 ohms

To find regulation of this transformer at a secondary load of 80 amperes at a power-factor of 70 per cent.

Equivalent ohmic resistance reduced to primary

$$R_1 = 1.3 + 0.0125 \times \left(\frac{1,000}{100}\right)^2 = 2.55 \text{ ohms.}$$

Equivalent inductive resistance reduced to primary

$$X_1 = 6.5 + 0.062 \left(\frac{1,000}{100}\right)^2 = 12.7 \text{ ohms.}$$

Current reduced to primary, $i_1 = 80 \times \frac{100}{1,000} = 8$ amperes.

Total ohmic drop, $i_1\ R_1 = 8 \times 2.55 = 20.4$ volts.

Total inductive drop, $i\,X_1 = 8 \times 12.7 = 101.6$ volts.

The corresponding diagram is shown in Fig. 34. $O\,D_2$ is secondary voltage reduced to primary circuit = 1,000 volts; i is the current and $D_2\,F\,D_1$ is the triangle of drop, where $D_2\,F = 20.4$ volts, and $F\,D_1 = 101.6$ volts. $O\,D_1$ then becomes 1,090 volts so that regulation under the given conditions of load is 9 per cent. Both resistances are taken somewhat high so as to make the diagram clearer.

For non-inductive load, the total drop would be but 2½ per cent. as $D_1\,F$ being perpendicular to i would also be perpendicular to $O\,D_1$ and have but little effect in reducing $O\,D_2$.

Instead of constructing a diagram, the drop can be found from Mr. Mershon's chart or Mr. Baum's calculating device. The diagram itself explains the application of these devices.

(5) *Experimental Determination of Inductive Resistance of a Transformer*—From the foregoing considerations it is evident that a knowledge of the value of equivalent inductive resistance of a transformer is necessary for a judgment of its regulation. It is hardly possible to calculate this resistance from the dimensions of a transformer with the same precision as its ohmic resistance can be calculated, because the paths of leakage in iron and in air are not known, and can only be assumed. But this equivalent inductive resistance can be easily determined experimentally on an actual transformer, by short-circuiting one of the windings and sending through the other full-load current. It is very much the same test as was previously explained for the determination of inductive resistance of a transmission line.

Strictly speaking, inductive drop in a transformer can be determined from any load test, if the currents and the voltages are measured, as well as the power-factors of the load in both circuits, and if the ohmic resistances of both winding have been determined already by the usual direct-current method. Referring to the diagram, Fig. 34, every line in this

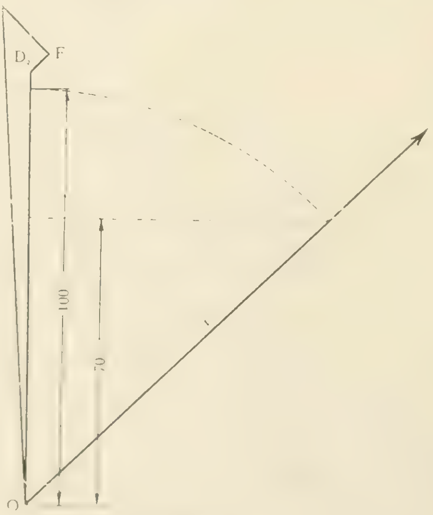


FIG. 34

figure is then known except $F\ D_1$ which can be measured from the diagram. But this method has two disadvantages. First, it is not always possible to test a transformer under full-load conditions, especially if it is a very large transformer designed for very high voltage. The second and more important objection is that the accuracy of such a measurement would be extremely small, because lines $O\ D_1$ and $O\ D_2$ are large as compared with the sides of triangle $D_2\ F\ D_1$. Hence, a small error in $O\ D_1$ or $O\ D_2$ would altogether change this small triangle.

It follows, therefore, that it is a great advantage to make these measurements under such conditions that both vectors, $O\ D_1$ and $O\ D_2$ are as small as possible, while the triangle $D_2\ F\ D_1$ is as large as possible. Both these conditions are fulfilled if we short-circuit the secondary of a transformer and send about normal current through the primary. In this case $O\ D_2$ equals 0, and diagram, Fig. 34, assumes the aspect of Fig. 35.

The ohmic resistance of both windings must be measured by direct current, and the base $F\ D_1$ can be measured graphically or calculated by the formula $F\ D_1 = \sqrt{e_1^2 - i^2 \left\{ r_1 + r_2 \left(\frac{n_1}{n_2} \right)^2 \right\}^2}$, from which the equivalent inductive resistance of the transformer can be found.

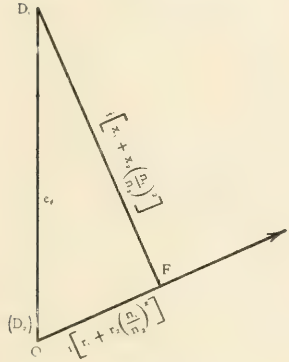

D_1
e_1
F
(D_2)
O
$i\left[x_1 + x_2\left(\frac{n_1}{n_2}\right)^2\right]$
$i\left[r_1 + r_2\left(\frac{n_1}{n_2}\right)^2\right]$

FIG. 35

After ohmic and inductive resistances and the ratio of a transformer are known, its regulation or drop can be determined for any load and any power-factor by means of the diagram Fig. 34.

(6) *Kapp's Diagram*—Mr. G. Kapp showed that it was not necessary to construct the diagram, Fig. 34, separately, for every power factor; besides it is not necessary to construct separate diagrams for drop and for regulation. All this can be done in the same figure. Let the triangle $A\ B\ C$ in Fig. 36 represent the triangle of voltage drop corresponding to the triangle $D_2\ F\ D_1$ in Fig 34. $A\ F$ is the direction of the current. The circle $K\ L$ is described from C with a radius equal to the applied primary e.m.f. (say 1,000 volts as in our former example). Then the lines like $A\ R_1$, $A\ R_2$, $A\ R_3$ etc., will represent secondary voltages reduced to the primary circuit (say 980 volts, 960 volts, and so on), corresponding to angles of lag $F\ A\ R_1$, $F\ A\ R_2$ etc. For the vector R_1 current is leading by the

angle $F\ A\ R_4$. This diagram is the same as Fig. 34. To show this, connect C to R_2 and draw $R_2\ F^1$ parallel to $A\ F$. Then the triangle $C\ R_2\ A$ is the same as $D_2\ O\ D_1$ on Fig. 34, and the angle $A\ R_2\ F^1$ represents angle of lag. The only difference is that in Fig. 34 direction of vector $O\ D_2$ was supposed to be fixed, and position of the triangle of drop was supposed to correspond to the variable angle of lag, while in Kapp's diagram, position of the triangle of drop $A\ B\ C$ is fixed, as well as that of the current vector $A\ F$, and the vectors of e.m.f. are drawn according to the value of the power-factor. This is done for the sake of convenience—not to plot separately the triangle $A\ B\ C$ for every power-factor.

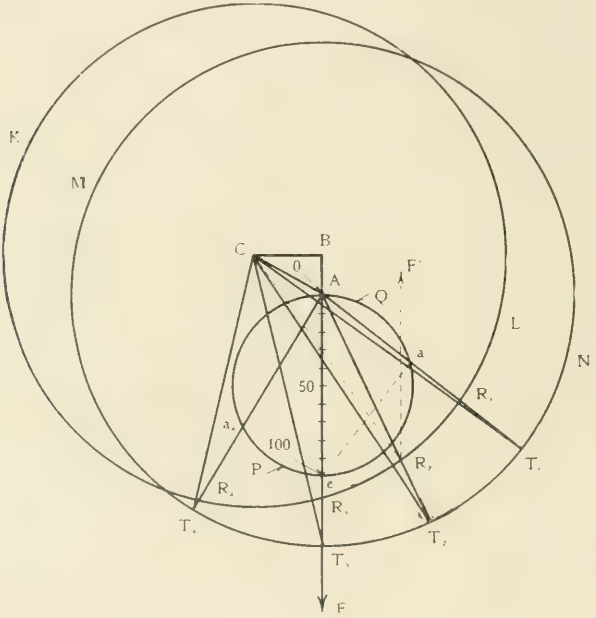


FIG. 36

Regulation of the transformer can be found from the same diagram. To that end a second circle $M\ N$ must be drawn with the same radius as circle $K\ L$, from the point A as a center. In this way we assume the secondary voltage as constant (say 1,000 as reduced to primary). Lines $C\ T_1\ C\ T_2\ C\ T_3$ etc., will represent primary voltages (say 1,030 volts, 1,050 volts) necessary to maintain that constant secondary voltage, 1,000 volts, at different power-factors.

A very convenient method to read off graphically the power-factor in percent. corresponding to a given angle of lag, is to describe a circle $P\ Q$ of an arbitrary radius, having its center on $A\ F$ and passing through A, and to divide its diameter into 100 parts. Chords $A\ a_1\ A\ a_4$ measured by this scale give the power factor in per cent. For instance, $A\ a_1$ in Fig. 36, corresponds to a lag of 70 per cent., $A\ a_4$ to a lead of 84 per cent., and so on. Thus the order of construction of this diagram is as follows:

(1) Determine the ratio of the transformer at no load; find out its ohmic resistances by direct-current method, and calculate its equivalent ohmic resistance R.

(2) Determine its equivalent inductive resistance X by short-circuit test as was described above.

(3) Reduce its secondary current to primary in inverse ratio of voltages.

(4) Construct the triangle $A\ B\ C$, having for its sides $i_1\ R$ and $i_1\ X$.

(5) Draw the two circles, $K\ L$ and $M\ N$, from the points C and A with a radius equal to the secondary voltage reduced to primary.

(6) Draw the small circle $P\ Q$ of power-factor.

Then the triangles like $A\ C\ T_1\ A\ C\ T_2$ will give all necessary information about drop and regulation at a given current i_1. $A\ R_1$ is the secondary voltage if the primary voltage is kept constant. $C\ T_1$ is primary voltage necessary to maintain the secondary voltage constant. $A\ a_1$ is the power factor to which the triangle $C\ A\ T_1$ corresponds. For good transformers the triangle $A\ B\ C$ is very small as compared to the dimensions of the circles, so that the whole diagram must be drawn to a large scale to measure, with due precision, differences of voltages. In many cases, it will be found more convenient to use Mershon's or Baum's charts instead of constructing a diagram. But the diagram gives a very good insight into the whole performance of a transformer under different load conditions.

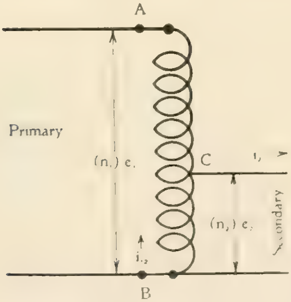


FIG. 37

(7) *Diagram of Auto-transformer.* An auto-transformer is a transformer having but one winding, as shown in Fig. 37. Primary voltage is usually applied across the total number of turns between points A and B, and the secondary circuit is connected between two taps taken from the same winding as between B and C. Ratio of voltages evidently is equal to the ratio of number of turns. If there are 200 turns be-

tween A and B, and 50 turns between B and C, secondary voltage at no load would be one-fourth the primary. These transformers are very convenient for pressure regulation, because several taps can be taken off at different points of the winding. They are used for starting induction motors, and for regulating the voltage of transmission lines; also in connection with rotary converters, and recently they have been successfully applied for regulation of the speed of single-phase series railway motors, by changing the voltage at the brushes of the motor.

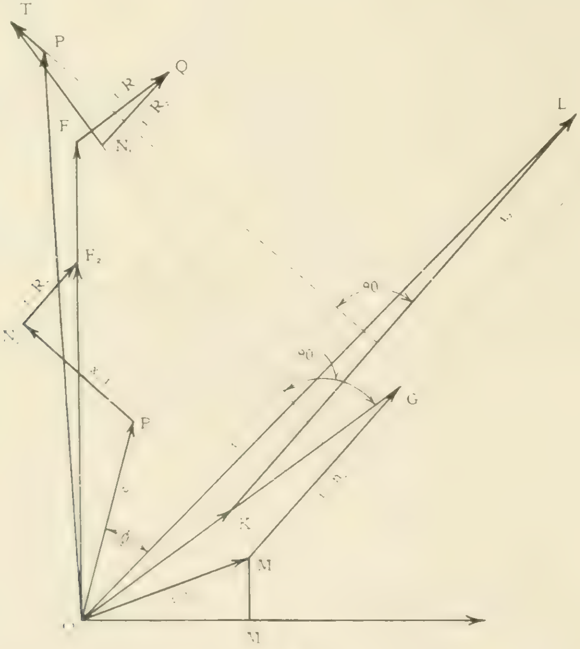


FIG. 38

The vector diagram of this kind of transformer can be deduced as follows:

Let i_1 Fig. 38, be the primary current, i_2 the secondary current, and i_{12} the current flowing in the transformer between the points C and B, Fig. 37. If n_1 is the total number of turns between A and B and n_2 number of turns between B and C, then the e.m.f.'s E_1 and E_2 induced by the magnetic flux will be as in the ratio of these numbers of turns, that is, $\frac{E_1}{E_2} = \frac{n_1}{n_2}$. Let $O F_1$ and $O F_2$ represent these vectors, Fig. 38; let Φ be the magnetic flux, and $O M^1$, as before, the magnetizing or more strictly no-load current of transformer, consisting of a magnetizing component $O M$ and a power component $M M^1$ for overcoming iron losses. Two conditions regarding the currents are to be fulfilled:

(1) The sum of the currents i_1 and i_{12} must give the secondary current i_2.

(2) Magnetizing effects of currents i_1 and i_{12} together must give magnetizing effect of the no-load current i_0 (see diagrams of ordinary transformer in Figs. 28 and 30, June issue.)

The first condition is expressed in diagram Fig. 38, by the triangle $O K L$, where $O K = i_1$ $K L = i_{12}$ and $O L = i_2$. The second condition is expressed by the triangle $O G M^1$, where each current is multiplied by the number of turns through which it is flowing in the transformer. Thus $i_1 (n_1 - n_2) - i_{12} n_2 = i_0 n_0$ (geometrical subtraction). To get the secondary terminal pressure e_2 ohmic and inductive drops between the points B and C, Fig. 37, must be subtracted from the induced secondary e.m.f. $E_2 = O F_2$ as it is shown by the vectors $F_2 N_2 = i_{12} R_2$ and $N_2 P_2 = i_{12} x_2$ where R_2 and X_2 are the ohmic and inductive resistances of the windings between the terminals B and C. In like manner, to get the primary impressed volts e_1 the total drop between the points A and B must be added to the induced primary counter e.m.f. $E_1 = O F_1$. The ohmic drop between A and B is equal to $i_1 R_1 - i_{12} R_2$ where R_1 is the ohmic resistance of the winding between A and B. The sign minus signifies that the positive directions of i_2 and i_{12} are opposite. In the same way inductive drop is $i_1 x_x - i_{12} x_2$. Fig. 38 represents a complete diagram of an auto-transformer. This diagram can be simplified in two respects, like the diagram of an ordinary transformer:

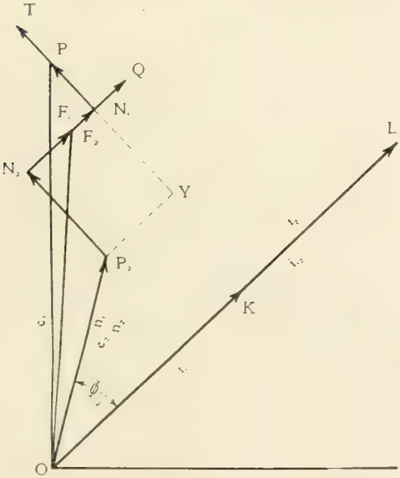


FIG 39

(1) For considerable load the magnetizing current i_0 can be neglected, as compared with load currents, so that both triangles $O K L$ and $O G M^1$ can be assumed to fall into one straight line and the condition $i_1 (n_1 - n_2) = i_{12} n_2$ is approximately fulfilled.

(2) The induced voltages $O\ F_1$ and $O\ F_2$ which are of no practical use, can be eliminated, so as to leave in the diagram only the primary and the secondary terminal voltages, as was done in Fig. 33.

This simplified diagram is represented in Fig. 39, and the final result in Fig. 40.

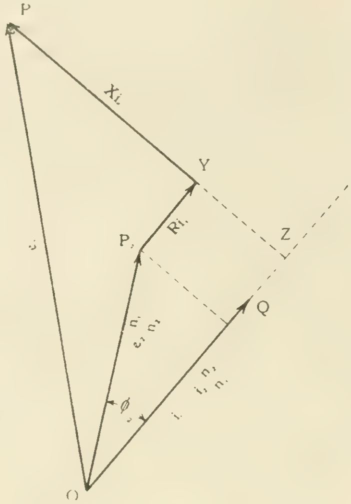


FIG. 40

Comparing these figures with figures 33 and 34, it will be seen that an auto-transformer has an equivalent ohmic resistance and an equivalent inductive resistance like an ordinary transformer, and that, consequently, its drop and regulation can be determined in just the same way as in an ordinary transformer. First of all the ratio of voltages $\frac{n_1}{n_2}$ and the ohmic resistances R_1 and R_2 have to be determined, then equivalent inductive resistance X can be calculated from short-circuit test (short-circuit the secondary between the points B and C). After this the diagram, as in Fig. 40, can be used for calculating the drop and regulation, or Kapp's diagram may be constructed. Mershon's or Baum's devices can also be used. The only difference from the ordinary transformer is in the expressions for equivalent internal resistance and reactance.

FACTORY TESTING OF ELECTRICAL MACHINERY—VII

By R. E. WORKMAN

(c) Loading a Motor by a Brake—This, the most direct method of loading a motor, is of use not only for determining the speed regulation of the motor, but also for directly determining its efficiency from the torque on the brake. Its drawbacks are that it cannot be used conveniently to load machines of large size for any length of time, and that, in any case, it is difficult to obtain a steady load. Brake tests are taken on motors of capacities less than about 100 horsepower.

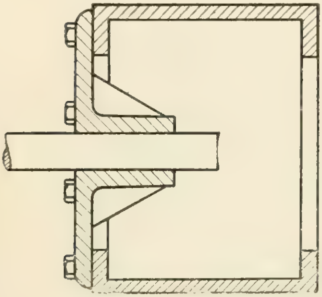


FIG. 33—FORM OF PULLEY USED IN BRAKE TESTS OF LARGE MOTORS

For large motors a brake of the form shown in Figs. 32 and 33 is used. The pulley is of the shape shown in Fig. 32. There is a flange on the outside end as shown to retain a layer of water in the pulley when it is rotating. The brake consists of strips of wood all around the pulley, held together by means of three strong steel straps. Under the wood is a sheet of asbestos, and under that, a sheet of brass, which bears directly on the pulley, and is kept well lubricated with grease. The tension is adjusted by means of a screw and hand wheel as shown in the illustration. The heat generated is carried off by means of a jet of water thrown into the pulley, and the water is drawn off by a scoop at the end of a large hose. For smaller motors the form of brake and pulley shown in Figs. 34 and 35 is used. The pulley is similar to that used with the large brake, but has flanges to prevent axial motion of the brake. The brake consists of a strong wooden arm to one end of which is fixed a block of wood about six inches broad and having its under side fitted to the surface of the pulley. A strap of sheet steel faced with canvas is fixed at one end to the arm by means of a bolt and passes around the pulley. The tension of the strap is adjusted at the other end, by means of a screw and hand wheel. A length of threaded steel bar is fixed into the other end of the arm by means of nuts, as shown, to rest on the platform of the scales. In this particular brake the diameter of the pulley is 12 inches, its breadth about 6 inches, and the length of the arm measured horizontally between the center of the shaft and a vertical line through the pin at the end when the arm is horizontal is 3 feet. The heat generated is carried off, as shown in Fig. 35, by means of a stream of water. As the brake is not balanced with the arm horizontal, it is necessary to subtract a constant amount from the readings of

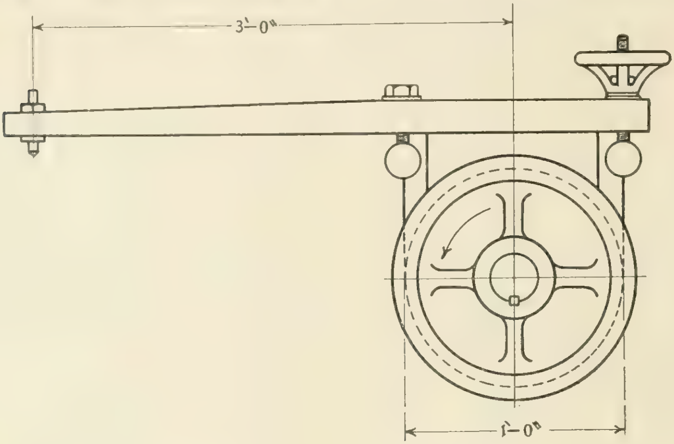


FIG. 34—FORM OF BRAKE USED IN BRAKE TESTS OF SMALL MOTORS

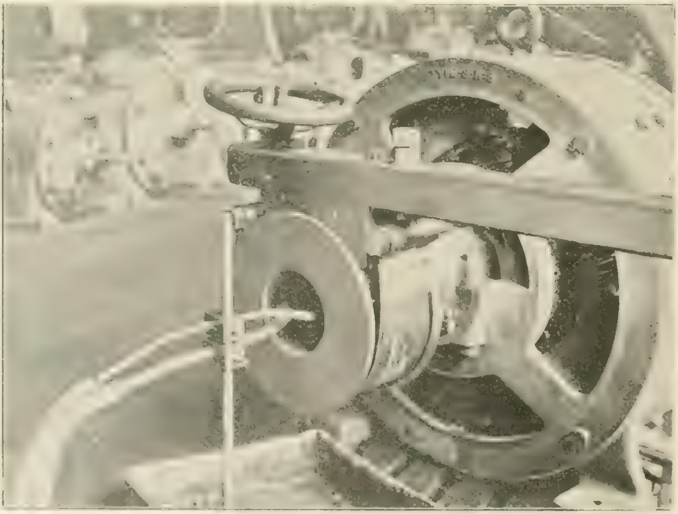


FIG. 35—DETAILS OF WATER SERVICE USED IN BRAKE TESTS

the weight on the scales. This quantity is found as follows: The brake is taken from the pulley and a line marked on its bearing surface which would be vertically above the center line of the pulley with the arm horizontal. The brake is supported by means of a V-shaped strip of wood on this line so that the arm shall be horizontal while the pin at the other end of the brake arm rests on the table of the scales. The weight measured on the scales, or the "tare" of the brake, will be the amount which is to be subtracted from all the readings taken, in order to obtain the true power absorbed by the brake.

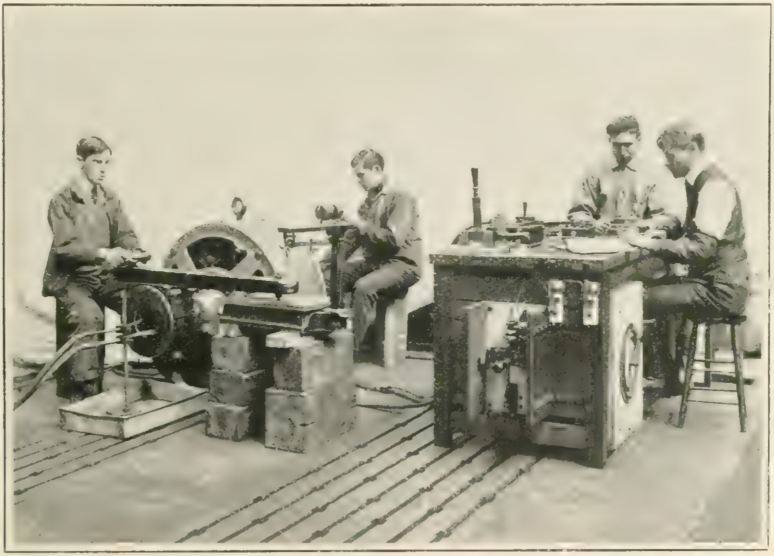


FIG. 36—BRAKE TEST ON DIRECT-CURRENT MOTOR

Preparations for Test—The connections shown in Fig. 37 are those for a brake test with an ordinary running test table: an iron-loss table may be used just as well with the ordinary connections for running a motor.

Conduct of Test—The motor is started and brought up to speed and the brushes are set on a trial full-load position. In the case of large motors, where a shunt regulating rheostat is used to obtain the correct speed, it is necessary to make first a trial at full load in order to adjust the amount of resistance in the shunt-field for correct full-load speed. The readings to be taken are: Terminal volts, armature current, shunt current, speed and weight on the scales.

In taking the readings, while a speed is being taken, the voltage must be held constant and the brake tension kept so as to give a constant armature current during each reading. This should give, at the same time, a constant brake reading. The current and the weight on the scales must be read simultaneously.

The shunt resistance having been adjusted, it remains to take a series of readings with different loads, the shunt resistance, brush position and voltage being held constant. A reading should then be taken with the brake off, first with the brush position unchanged and then with the brushes on no-load neutral and the same field current as before; the armature input from this last reading gives the sum of friction and iron losses in the motor.

Precautions to be Observed—It is important, especially in the case of small motors, to take all readings with either an increasing or decreasing strength of field, i. e., in a compound-wound motor, where the speed drops with an increase of load due to the strength-

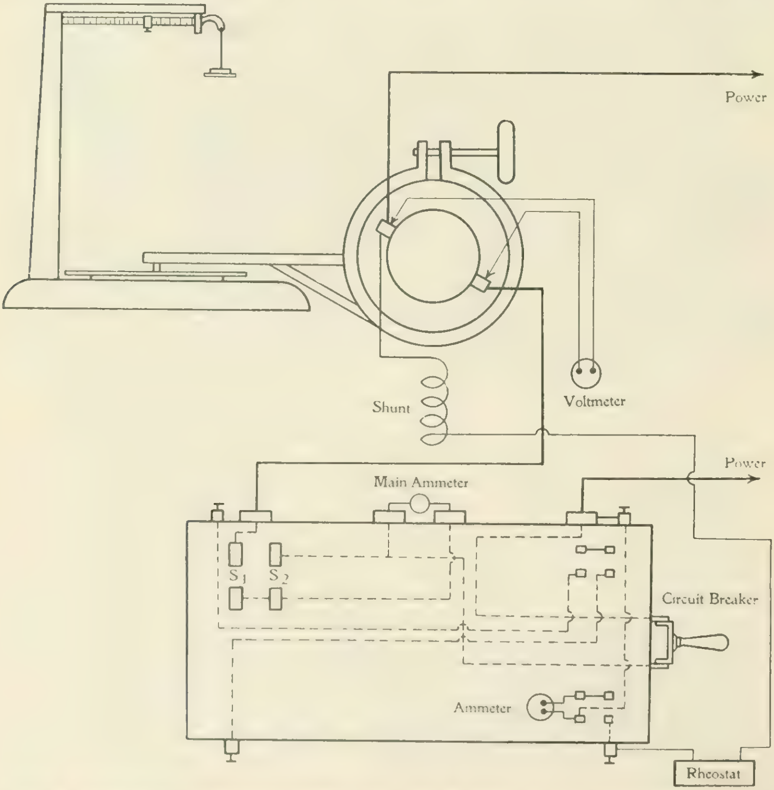


FIG. 37—DIAGRAM OF CONNECTIONS FOR BRAKE TEST ON DIRECT-CURRENT MOTOR

ening of the field, different speeds will be obtained if the regulation curve is taken with an increasing and a decreasing load. The regulation curve obtained by any of the above mentioned methods will be the same. An example is given in Fig. 38 of the curve obtained in an actual test of a 28-h. p., 220-volt, 810 r. p. m., 4-pole shunt-wound motor.

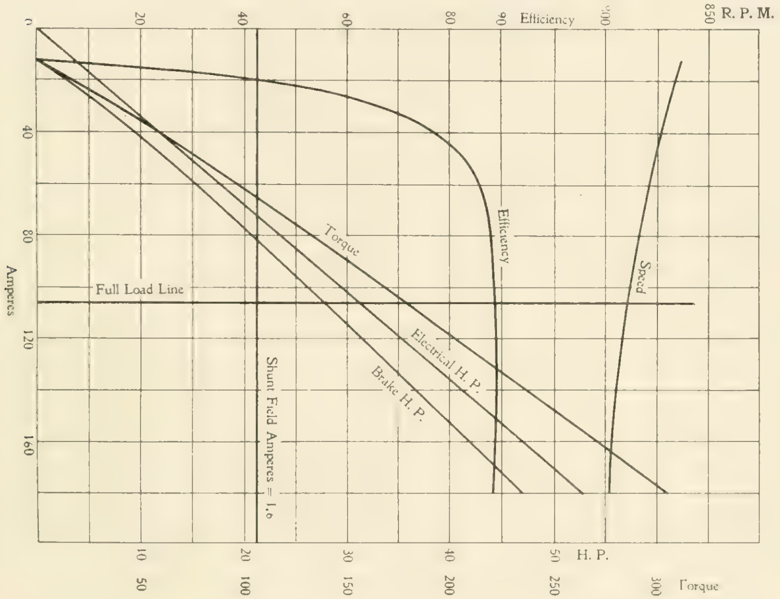


FIG. 38—PERFORMANCE CURVES OF DIRECT-CURRENT MOTOR

EFFICIENCY TESTS—The efficiency of a motor may be found in two different ways: (1) From losses, or (2) from brake test.

(1) EFFICIENCY OF A MOTOR FROM LOSSES—The data required are: the resistance of the copper circuits of the machine, curve of iron-loss plotted to induced e.m.f., bearing friction and windage loss, brush friction loss, a speed regulation curve and the number and dimensions of the brushes.

Except the speed regulation curve, these data are all found in the same way as for a generator. There are certain differences, however, in their use:

(a) The terminal voltage is the sum of the induced voltage and the volts drop in the armature, not the difference as in the case of a generator. Thus in finding the induced voltage for reading off the iron-loss from the curve for each point, the IR drop in the armature must be subtracted, not added.

(b) The losses must be subtracted from the input in order to find the output, instead of added to the output to find the input.

(c) The curves of input and output are plotted in horse-power instead of kilowatts.

(d) A curve of torque is calculated from the speed curve and the curve of horse-power output (brake horse-power), from the relation,

$$\text{brake horse-power} = \frac{\text{speed} \times \text{torque} \times 2\pi}{33000}$$

$$= \text{speed} \times \text{torque} \times .0001904.$$

The torque is calculated for a series of points and plotted with the other quantities. The following indicates the method of calculation of one point on the efficiency curve of the above mentioned 28-h. p. shunt-wound motor.

Armature current=100 amperes.

Shunt field current=1.63 amperes.

Total current=101.6 amperes.

Terminal voltage=220 volts.

Speed 813 r.p.m.

Copper Losses:

Armature resistance reduced to its equivalent at 50° C.=.0543 ohm.

Shunt field resistance reduced to its equivalent at 50° C.=119.5 ohms.

(i) I^2R loss in armature=543 watts.

(ii) I^2R loss in field=358 watts.

Area of half the total number of brushes=3.5 square inches.

Current density=28.6 amperes per square inch.

Volts drop in brushes=1.7.

(iii) I^2R loss in brushes=170 watts.

IR drop in armature=5.4 volts.

Drop in brushes and leads=2 volts.

Induced volts=212.6.

(iv) Iron loss (from curve, for 212.6 volts)=910 watts.

(v) Bearing friction and windage loss (from loss test)=233 watts.

(vi) Brush friction loss (from loss test) = 167 watts.

(vii) Total loss (i+ii+iii+iv+v+vi)=2381 watts.

(viii) Input=22.35 kw.=30 h. p.

(ix) Output=(Input-losses)=19.97 kw.=26.8 h. p.

(x) Efficiency=89.3 percent.

(xi) $$\text{Torque} = \frac{33000}{2\pi} \times \text{brake horse-power} / \text{speed} = \frac{5252 \times 26.8}{813} = 173 \text{ lb. ft.}$$

EFFICIENCY OF A MOTOR FROM BRAKE TEST—The speed regulation and torque curve of the motor may be determined by means of a brake test as described above under "Regulation," or the speed regulation curve and the torque curve may be determined separately: the former by means of a test with the motor belted to a generator loaded in a convenient manner and the latter by a brake test. The latter method has the advantage that a much steadier load can be obtained while speeds are being taken. It is important to see that no change is made in the resistance in the shunt field or in the position of the brushes between the regulation and the torque tests, and also that both tests are made under the same conditions, as regards increasing or decreasing load.

The following readings, taken on the above mentioned 28-h. p. shunt-wound motor will serve as an example:

Back lead on brushes, ¾ of one bar.

Brake-arm length, 2½ ft.

Tare of brake, 2 lb. 10 oz.

TERMINAL VOLTS	ARMATURE AMPERES	FIELD AMPERES	R. P. M.	WEIGHT ON SCALES	LB.—FT. TORQUE	H. P.		EFFICIENCY
						B.H.P.	INPUT	
220	102	1.63	813	72 lb. 10 oz.	175	27.1	30.6	88.6%
220	6.6	1.63	813	0	0	No-load reading brushes on no-load neutral		

The input to the motor in watts is found by multiplying the volts by the sum of the armature and shunt amperes. This is reduced to horse-power by dividing the number of watts by 746, or approximately by increasing the number of kilowatts by one-third.

The torque is found from the reading of the weight on the balance by subtracting from that quantity the tare and multiplying the result by the length of the brake-arm. As the weight is taken in pounds and the brake-arm length in feet, the torque is given in pound feet.

The output of the motor in brake horse-power is found by the product of the torque, the speed and $\frac{2\pi}{33,000}$ or .0001904.

The efficiency is the percentage relation of output to input. The no-load loss or the sum of friction and iron losses is found by multiplying the armature amperes by the voltage, the result being in this case 1450 watts. The efficiency curve, curves of input, output, torque and shunt field amperes for this motor are shown in Fig. 38.

Shunt Regulation of Motors—In the case of variable-speed shunt and compound-wound motors, the shunt regulation is taken. This curve, which is a speed curve for constant armature current with varying field currents, is taken to ascertain the limits of speed within which the motor will work satisfactorily, and to give data for the determination of a suitable speed regulating rheostat.

Preparations for Test—The machine is belted to a generator and the table connections made as for an ordinary regulation test, the method of loading used being that most suitable for the size of motor.

Conduct of Test—The machine is started up and the brushes set with a definitely known back lead. Two sets of readings are to be taken, one set with decreasing field current and increasing speed, the other with increasing field current and decreasing speed, the terminal voltage and armature current being held constant throughout

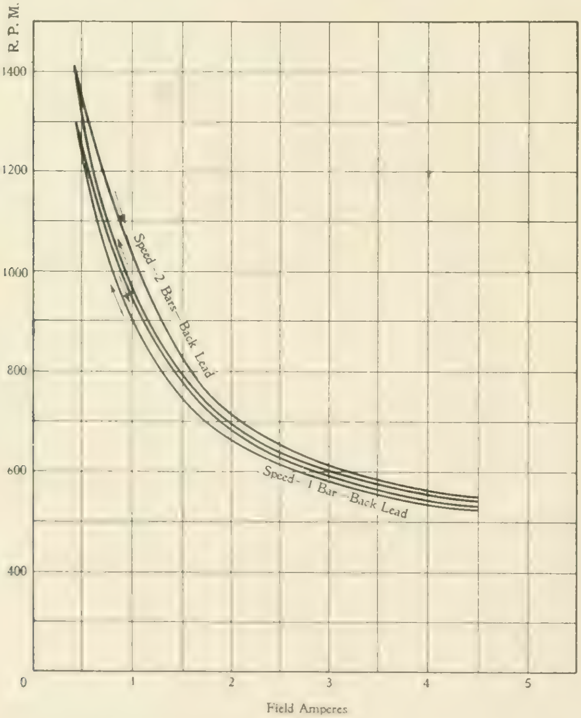


FIG. 39—SHUNT REGULATION CURVES OF COMPOUND-WOUND MOTOR

The readings recorded are: speed, field amperes, armature amperes and terminal volts, and notes are also taken of the commutation at different speeds. A start is made with no external resistance in the shunt field and the speed is increased to a specified amount or until the commutation becomes very bad; the field current is then raised again and brought gradually to its full amount.

Precautions to be Observed—It is important that, while taking a curve the field current be either continuously increased or decreased, as the case may be. As in the iron-loss test, if, in regulating, the field current is taken beyond its proper value and then brought back to it, errors will be introduced, owing to the retentivity of the iron of the field. The curves for a 15-h. p., 230-volt, 575-1150 r.p.m., 4-pole compound-wound motor are plotted as shown in Fig. 39, the higher curve being that obtained with an increasing field current. Two tests were made, one with one bar back lead, the other with two bars back lead. It was noted that with one bar back lead, there was a very slight sparking above 1137 r.p.m. With two bars back lead there was a very slight sparking from 1112 to 1400 r.p.m., but there it began to grow worse.

SHOP EXPERIENCE

SERIES RESISTANCE FOR THE TYPE F ALTERNATING CURRENT VOLTMETER.

In order that a voltmeter of the induction type, consisting of an aluminum disc revolving in the air-gap of an electro-magnet, may not be affected by small changes in frequency, it is necessary to insert a non-inductive resistance in series with the instrument.

The pull on the rotating disc varies as the strength of field times the induced current in the disc. This current in turn is proportional to the voltage induced in the disc, which is proportional to the field times the frequency; therefore the pull on the disc is proportional to the square of the field times the frequency, or since the field is proportional to the line current:

$$Pull = constant \times c^2 \times f$$

where c = line current, and f = frequency.

If the voltmeter contains a very high inductive resistance, the current will vary inversely as the frequency, hence:

$$Pull = constant \times 1/f^2 \times f = constant \times 1/f.$$

If, on the other hand, the voltmeter contains a very high non-inductive resistance, the current will be independent of frequency, and:

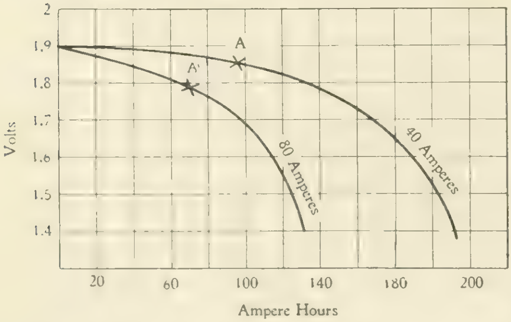
$$Pull = constant \times f$$

We thus have two extreme conditions, one where the pull is inversely proportional to the frequency, and the other where the pull is directly proportional to the frequency. By inserting a non-inductive resistance in series with the inductive resistance of the voltmeter, these two conditions may be so proportioned that the instrument will not be affected by small changes in frequency. For large changes in frequency, as 60 to 25 cycles, a readjustment will be necessary since, for correct reading, the instrument must have the same power factor and consume the same amount of energy on all frequencies.

AUTOMOBILE VOLTMETER

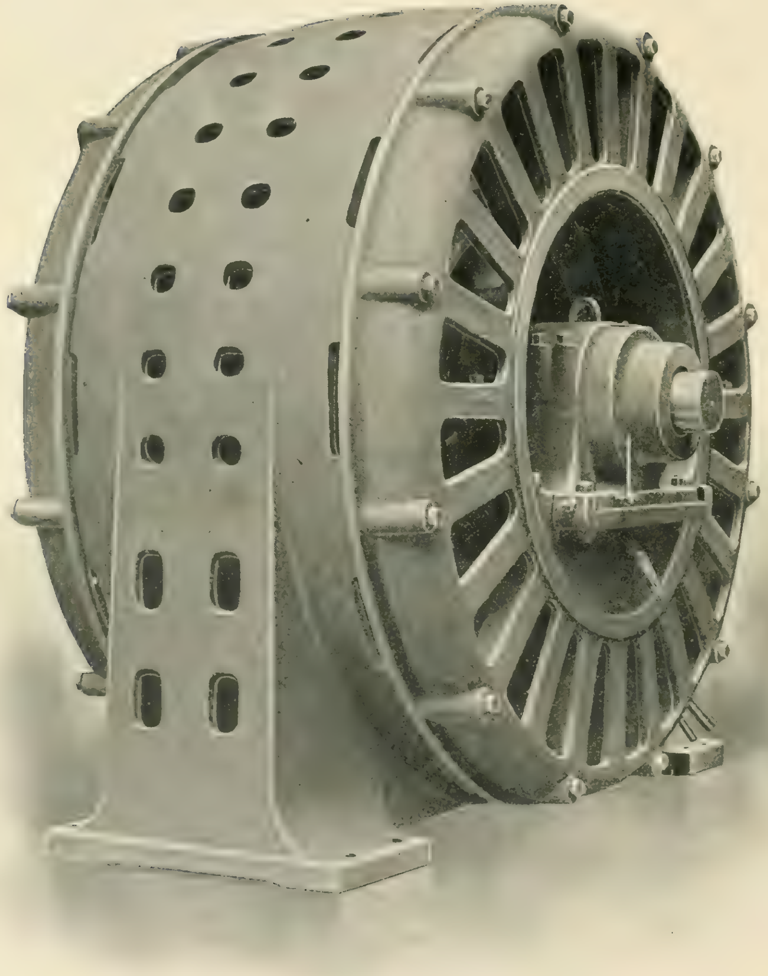
The development of the electric automobile has created a demand for an instrument, capable of withstanding hard service, which will indicate the amount of useful charge in a storage battery during any rate of discharge.

For any given rate of discharge, a storage battery will give a certain discharge curve, the number of ampere-hours given out by the battery before reaching its "discharged" condition, decreasing with higher rates of discharge, as shown by the accompanying curves.



The voltage across the battery on open circuit, alone is no indication of the remaining useful charge; that the voltage across the battery with a given current flowing is equally misleading, may be shown as follows: taking *A* and *A*^{1} as the *Half-Full* points on the 40 and 80 ampere discharge curves respectively, an instrument indicating *Half-Full* on the voltage represented by the point *A*, will evidently indicate that the battery is less than half full on the voltage represented by the point *A*^{1}; therefore, in order that the instrument will correctly indicate the half-full point for any rate of discharge, it must read the voltage across the battery, plus an amount approximately proportional to the current flowing; that is, it must be a voltmeter, with an additional series coil.

The instrument consists of an iron core wound with a shunt and a series coil and has a scale marked *Empty*, *Half-Full* and *Full*. The core is fitted with a pole piece so shaped as to produce a scale proportional to the ampere-hour discharge, which attracts a soft iron armature actuating the pointer shaft, the motion being controlled by a strong spring. As no jewels are used, the instrument is not sensitive to vibration.



2000 H.P. INDUCTION MOTOR

One of the three machines used in pumping water for the Cascade at the Louisiana Purchase Exposition, St. Louis, Mo.

THE
ELECTRIC CLUB JOURNAL

VOL. I SEPTEMBER, 1904 NO. 8

THE POLYPHASE INDUCTION MOTOR[*]

IN TWO PARTS—PART I

By B. G. LAMME

THE polyphase motor is usually treated from the theoretical standpoint, and the results obtained are of interest mainly to designers and investigators. Such treatment has been principally of a mathematical nature, the object being to show how the various characteristics of the motor may be predetermined. That is what the designer requires, but it gives very little information to the practical man, who uses the motor. In the following treatment of the subject, the general operation of the motor will be explained in a non-mathematical way by the use of diagrams which illustrate its characteristics under different conditions. Only the non-synchronous type of motors will be considered, and no distinction will be made between two and three-phase motors, for, if properly designed, they are practically alike in operation.

It is necessary to understand the characteristics of the polyphase motor in order to consider properly its application to the different classes of work to be met with in practice. These characteristics can be presented in the most intelligible manner by means of curves, which represent the relations between the speed, torque or turning effort, horse-power expended and developed, amperes, etc. The speed-torque curve, which represents the speed in terms of the torque, is the most important one, as upon this depends the adaptability of the motor to the various kinds of work. The starting conditions also depend upon the speed-torque characteristics. The other curves that are of importance in practice are the current, efficiency and power-factor. As these are dependent, to some extent, upon the speed-torque curve, this will be considered first. Before treating of its characteristics, a short description of the motor itself will be given.

A Paper Presented at the Twentieth National Electric Light Convention, Niagara Falls, June 10, 1897.

Construction and Winding.—The polyphase motor, like a direct-current motor, consists primarily of two parts, one stationary and the other rotating, each of which carries windings. The inside bore, or face, of the stationary part is generally slotted, and carries windings that resemble those of the rotating part, or armature of an ordinary direct-current motor without the commutator. The rotating part is also slotted on its outside face, and there are windings in the slots. Both cores, or bodies, are built up of thin iron or steel plates. The general arrangement is shown in Fig. 1. One of these windings, generally that on the stationary part, receives current from a two or three-phase supply circuit. The coils of this winding, although distributed symmetrically over the entire face of the core, are really connected to form distinct groups which overlap each other. These windings form the two or three circuits in the motor. When alternating electromotive forces are applied to these circuits, currents will flow which set up magnetic fields in the motor. These alternating fields in turn generate electromotive forces in the windings. Part of the current flowing in the windings represents energy expended usefully, or in heating,

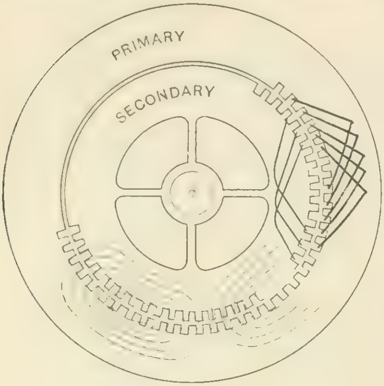
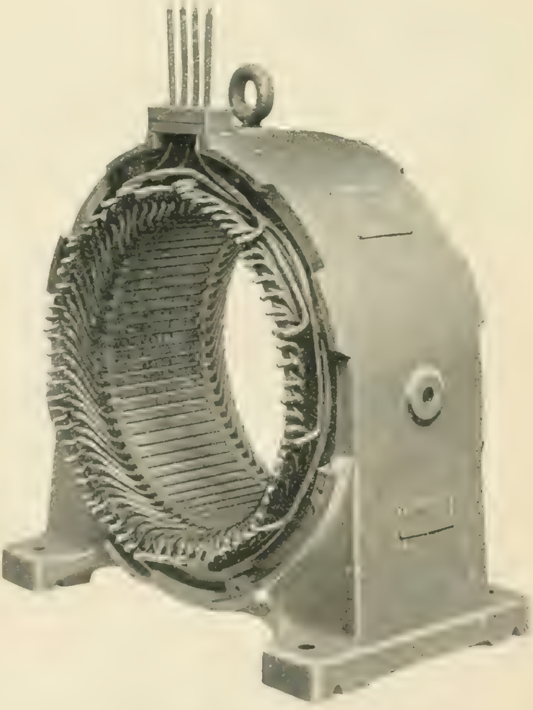


FIG. 1



PRIMARY OR STATIONARY PART OF INDUCTION MOTOR and part serves merely as magnetizing current. The latter, like the magnetizing current of a direct-current machine, is dependent upon the dimensions of the magnetic circuit and upon the magnetic density in the various parts. Even when the motor is running with no load the magnetizing current is required.

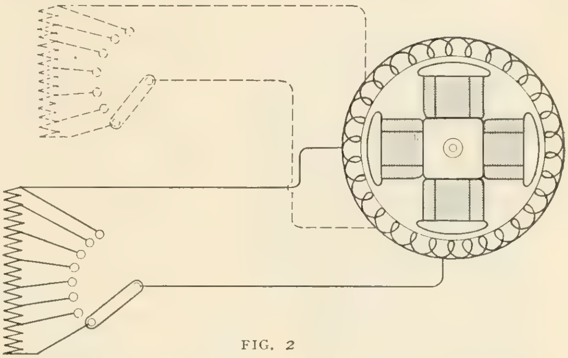


FIG. 2

The second part of the motor, generally the rotating part, receives no current from the supply circuit. The magnetic fields set up by the first set of windings pass through the second windings, and, under certain conditions, generate electromotive forces in them. If the second windings are arranged to form closed circuits, currents will flow in them. These currents are entirely separate from those of the supply circuits.

Speed and Slip.—When running, the motor has a maximum speed that is approximately equal to the alternations of the supply circuit divided by the number of motor poles in each circuit. This is the no-load speed. As the motor is loaded, the speed falls off almost in proportion to the load. The drop in speed is sometimes called the "slip." This is usually expressed in percent of the maximum speed. If, for instance, a motor has a maximum speed of 1,000 revolutions and drops fifty revolutions below this at full load, it has then a slip of five percent.

Torque and Armature Current.—With this type of motor, a drop in speed is necessary for developing torque. A fairly simple illustration of this action may be obtained by considering the operating of an alternating-current generator under certain conditions. We will take a type of alternator having a stationary armature and a rotatable field magnet, which can be driven at various speeds. Leads are carried out from the armature to adjustable resistances. To avoid complexity, the armature circuits and the resistances are considered as non-inductive. The field coils are excited by direct current. Fig. 2 shows this arrangement.

When the field is rotated at a certain speed, with the field coils charged, there is an alternating electromotive force set up in the armature winding. When the armature circuit is closed through a resistance, a current will flow and the armature will develop power. The power developed by the armature is slightly less than the power expended on the field shaft, which is proportional to the product of the speed and the turning or driving effort—i. e. torque—on the shaft. Consequently, at a given speed, a driving effort is required at the field shaft, corresponding to the power developed by the armature. If the armature current is increased or decreased, the power developed is increased or decreased also, and the driving effort will vary in proportion.

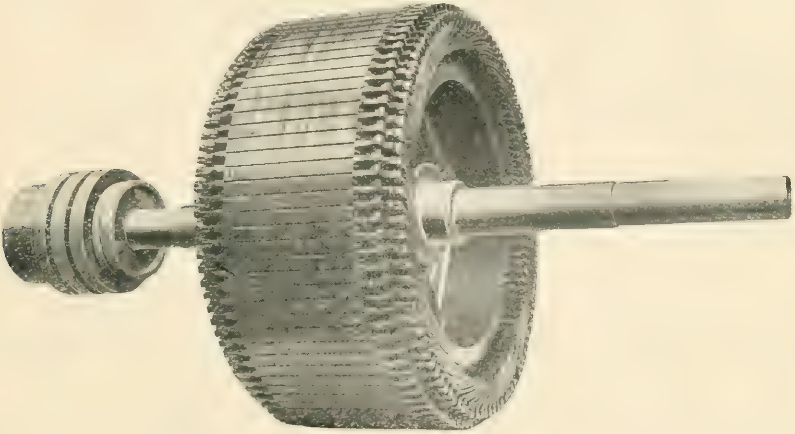
CAGE-WOUND SECONDARY OR REVOLVING PART OF INDUCTION MOTOR

Let the field now be rotated at one-half the above speed. The armature electromotive force becomes one-half what it was before. Reducing the resistance in the armature circuit also to one-half, the same current as before will flow. The power developed by the armature is now one-half and the speed of the field is one-half, consequently the driving effort or torque is the same as before. Reducing the speed further, and decreasing the resistance in the armature circuit in proportion, to keep the armature current constant, we find the driving effort on the field remains constant. Finally, if we reduce the speed so much that the external armature resistance is all cut out, and the armature is short-circuited on itself with the same current as before, the same driving effort is still required.

The field is now rotating very slowly, and the alternations in the armature are very low, being just sufficient to generate the electromotive force required to drive the armature current against the resistance of the windings. Any further reduction in speed will diminish the armature electromotive force, and hence the armature current must fall, the power developed be diminished and the driving effort also fall in proportion. An increase in speed will increase the armature current and thus increase the driving effort required.

If but one armature circuit is closed, the power developed will pulsate as the armature current varies, from zero to a maximum value, and the driving effort will also vary. But if the armature has two or more circuits having different phase relations, it may develop power continuously and the driving effort will then be continuous.

Illustration of "Slip."—The armature has been considered as stationary and developing power while a certain driving effort was applied to the field. According to the well-known law that any force is met by an opposing force, the armature must have a certain resisting effort. The armature really tends to rotate with the field, and the resisting effort is exerted to prevent this.



COIL-WOUND SECONDARY PART OF INDUCTION MOTOR, FOR STARTING WITH RESISTANCE IN SECONDARY CIRCUIT

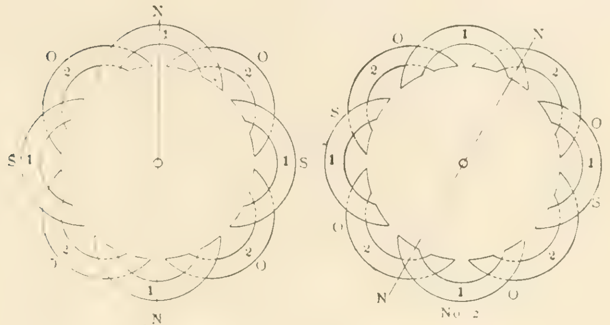
Assume the armature to be arranged for rotation, but locked, in the above operations. Release the armature, attach a brake, and adjust for a torque equal to the resisting effort of the armature. The armature just remains stationary. Speed up the field, and the armature will speed up also, keeping a certain number of revolutions behind the field. This difference in speed is that required for generating the electromotive force necessary for sending the current through the armature. The alternations in the armature will remain constant for a given armature current, independent of the speed at which the armature is running.

If the brake be tightened, the armature must drive more current through its windings to develop the required effort, the armature alternations must hence increase, and the armature will therefore lag behind its field more than before, or the "slip" is increased. If the brake be loosened, the armature will run nearer the speed of the field. If the field be driven at a constant speed and the brake be released, the armature will run at practically the same speed as the field.

If the winding consists of but one closed circuit, the torque developed by the armature varies periodically, and that developed by the brake will vary also, but to a less extent, as it is steadied by the inertia of the rotating armature. But with two or more circuits having different phase relations, arranged for constant power developed in the armature windings, the torque developed is also constant at all times. Consequently, for constant torque at the brake, there should be two or more phases in the armature windings.

Difference between Illustration and Actual Case.—This explanation of the development of torque in the short-circuited armature is merely an attempt to illustrate certain of the actions in the polyphase motor armature by a comparison with the operations of other apparatus, that is, in general, much better understood. We cannot infer, from the above illustration, that an alternating current generator would run as a motor under the assumed conditions, for, in the above operations, mechanical power is supplied to the field shaft, and mechanical power is delivered by the rotating armature to the brake. There is no true electro-motor action; that is, there is no transformation of electrical power supplied to mechanical power developed.

The action of the short-circuited armature of the above generator and that of the polyphase motor are very similar in regard to drop in speed for developing torque. But, in the polyphase motor, instead of the mechanically rotated field magnet, there is a stationary core provided with two or more windings which carry currents having different phase relation. These windings are placed progressively around the core, either overlapping or on separate poles. When the currents flow in the windings, resultant magnetic poles or fields are formed, which are progressively shifting around the axis of the motor. The closed or short-circuited armature, rotating in this field, develops torque by dropping in speed, in the same way that it develops torque with mechanically rotated field magnets. But electrical power, instead of mechanical, is now supplied to produce the shifting of rotating field, and the conversion from electri-

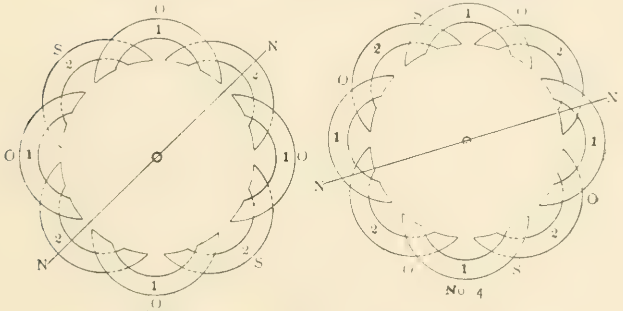


No. 1

Circuit 1 at Maximum Current.
Circuit 2 at Zero Current.

No. 2

Circuit 1 with Decreasing Current.
Circuit 2 with Increasing Current.

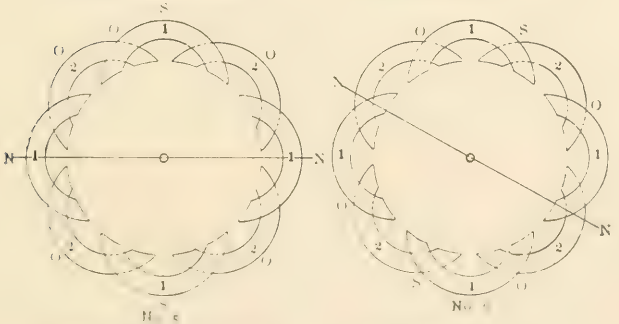


No. 3

Circuit 1 at Zero Current.
Circuit 2 at Maximum Current.

No. 4

Circuit 1 Increasing in Reverse Direction.
Circuit 2 Decreasing.



No. 5

Circuit 1 at Maximum in Reverse Direction.
Circuit 2 at Zero.

No. 6

Circuit 1 Decreasing.
Circuit 2 Increasing in Reverse Direction.

FIG. 3

cal power supplied to the field windings to mechanical power developed by the armature shaft is a transformer action which does not appear in the above illustrations.

Rotating Magnetic Field Electrically Produced.—Fig. 3 shows diagrammatically a progressively shifting field with two overlapping windings arranged for two-phase currents. Coils 1-1, etc., form one circuit, while coils 2-2, etc., form the other. Starting with the instant when the current in 1 is at its maximum value, the magnetiziing force of this set of coils must be at its maximum. The current and magnetizing force of circuit 2 are at zero value. Four poles or magnetic fields, alternating *N*-*S*-*N*-*S* around the core, are formed directly over coils 1. As the current in 1 begins to decrease, that in 2 rises. We then have the combined magnetizing forces of the two overlapping windings. These two magnetizing forces act together at some points, and oppose at others. The resultant magnetic field shifts to one side of the former position. As the current in 1 gradually falls to zero and 2 rises to its maximum value, the magnetic field shifts around until it is directly over coils 2. If the current in 1 should next increase in the same direction as before, while 2 diminished, the magnetic poles would shift back again to their former position. But the current in 1, after reaching zero value, rises in the opposite direction, while that in 2 falls. This shifts the resultant poles forward instead of backward, and they gradually shift ahead until they are again directly over coils 1. But the *N* poles have shifted around until they now occupy the former position of the *S* poles. Thus, with the current in 1 passing from a maximum in one direction to a maximum in the opposite, the poles have shifted forward the width of one polar space. Current in 2 next rises in a reversed direction, and the poles shift forward until when the current in 2 is a maximum they are over coils 2.

The diagrams, Nos. 1, 2, 3, etc., show the positions of the shifting field under certain conditions of current in the two circuits. In No. 2, the position shown is an arbitrary one, for it depends upon the relative values of the currents in the two circuits. With the two currents equal, the position of the line *N*-*N* would be half-way between coils 1 and 2.

These diagrams show that the magnetic field due to two-phase currents in properly arranged windings shifts progressively around the axis, just as if the field were rotated mechanically.

Speed-Torque Curve.—In polyphase motors, the part that resembles the field in the above description, and which receives the current from the line, is usually called the primary, on account of its electrical resemblance to the primary of a transformer. The equivalent of the armature in the preceding description is called the secondary. If the alternations of the supply circuits are constant, the reversals of the current in the field or primary will occur at a uniform rate, and the magnetic field will shift around its center at a definite speed, depending upon the rate of alternation of the supply circuit and the number of poles in each circuit of the motor. If the armature or secondary rotates at the same speed as the field shifts, there will be no reversals or alternations in its magnetism, and there will be no currents and, consequently, no torque. If a load is thrown on, the speed will drop, and the resultant alternations in the secondary will generate electromotive forces which will drive currents through the windings, and thus develop torque. The speed will continue to fall, and the secondary electromotive forces will continue to increase until a torque sufficient for the load is developed. Increasing the load on the motor, the speed should fall and the torque increase until zero speed is reached. The speed-torque curve would then be of the form shown in Fig 4, curve "a." But the shape of this curve is modified to a great extent in actual motors by certain effects which cannot be entirely eliminated.

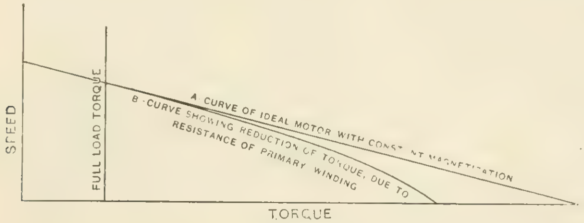
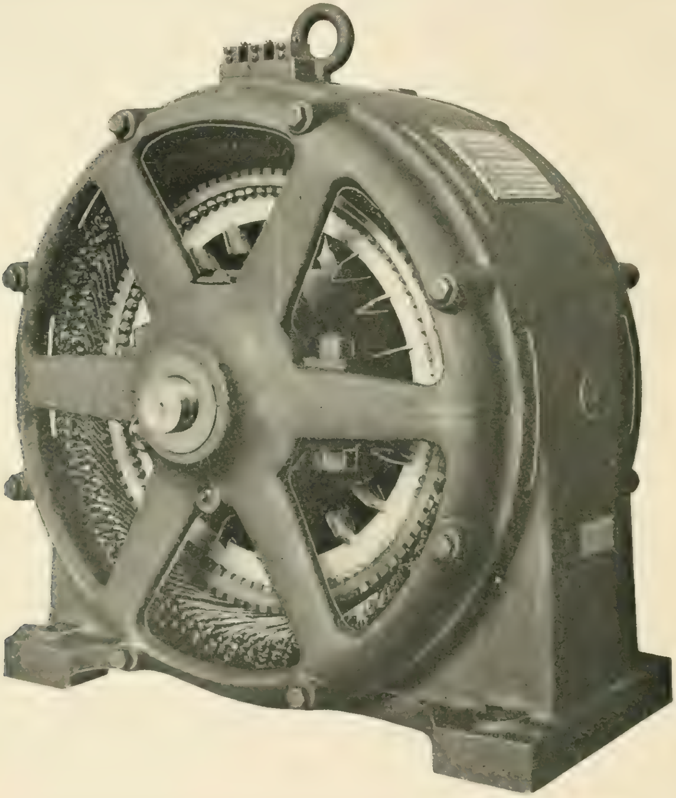


FIG. 4

Primary Resistance Reduces Magnetization at Heavy Loads.—In the case of the revolving field, the magnetization was supposed to remain constant under different conditions. But in the motor primary, the magnetism of the primary is not constant under all conditions, and it does not all pass through the secondary circuits. The primary windings necessarily have some resistance, and a certain electromotive force is required to drive the primary current through the windings. With a constant applied electromotive force, the primary counter-electromotive force will diminish as the drop due to primary resistance increases, and the magnetic field required will diminish also. Consequently to develop the required secondary electromotive force for driving the secondary current through the windings, the speed must drop more than shown by curve "a" in Fig. 4. This gives a speed-torque curve as shown by curve "b" in Fig. 4. Instead of being a straight line it is somewhat curved.



50-H.P. 3-PHASE INDUCTION MOTOR WITH CAGE-WOUND SECONDARY

Magnetic Leakage Limits Maximum Torque.—But there is a still more important effect in the motor. The primary and secondary currents, and their consequent magnetizing forces, are opposed to each other. The result is that part of the primary magnetism threads across between the primary and secondary windings without passing into the secondary. Thus, the electromotive force of the secondary is reduced, or, for a required secondary electromotive force, the secondary alternations must be increased. This means a further drop in speed.

The secondary currents also tend to form local magnetic fields around their own coils. These local fields are alternating, and set up electromotive forces in the secondary circuits. In consequence, the electromotive forces generated by the magnetism from the primary have to drive currents, not only against the resistance of the secondary windings, but also against these local electromotive forces. This necessitates a further drop in speed for the required torque. These local electromotive forces depend upon the secondary alternations, and therefore vary with the drop in speed, and are greatest at zero speed. This introduces a very complicated condition in the secondary circuits. These magnetic fields, which thread around only the primary or secondary windings, are called the magnetic leakages, or stray fields, or the magnetic dispersion.

If the magnetic leakage is relatively large, that is, twenty to twenty-five percent of the total induction, and the secondary resistance is low, the speed-torque curve will have the peculiar shape shown in Fig. 5. This curve shows the torque increasing as the speed falls, until a certain maximum is reached. Beyond this point the torque diminishes with further drop in speed. If the motor is loaded to the maximum torque, a slight increase in load causes a further drop in speed, the torque diminishes and the motor stops. As a consequence, the normal rating of the motor must be considerably below this "pulling-out point." The margin necessary depends upon the nature of the load to be carried.

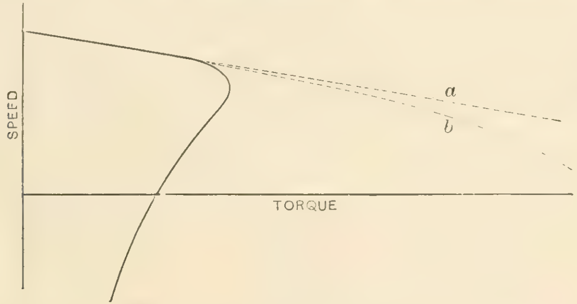


FIG. 5

The starting torque, speed regulation, etc., of the polyphase motor depend upon the form of the speed-torque curve. The different methods of varying the form of these curves will be considered next.

Effect of Secondary Resistance on Speed Curve.—As the secondary electromotive force is that necessary to drive the secondary currents through the windings, it follows that the electromotive force required must depend upon the resistance of these windings.

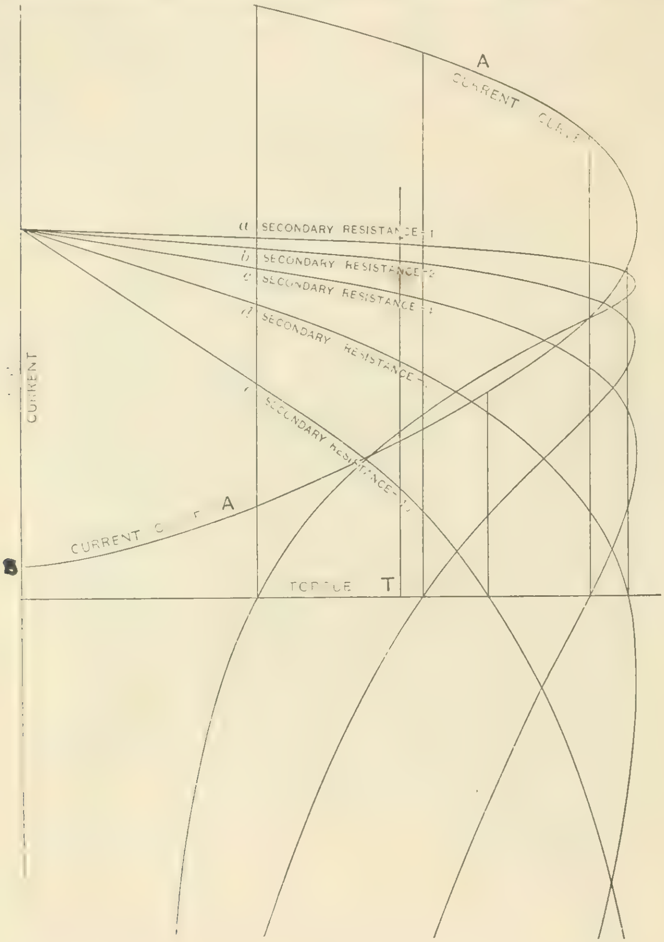


FIG. 6

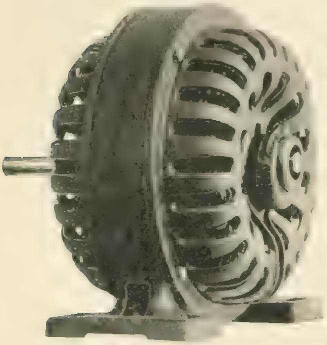
A larger resistance means a larger electromotive force for the required current, and, therefore, a greater number of secondary alternations, or a greater drop in speed. The torque being held constant, any variation of the secondary resistance requires a proportionate variation in the slip. If the slip with a given torque is ten percent, for instance, it will be twenty percent with double the secondary resistance, or fifty percent with five times the resistance. This is true only with the primary conditions of constant applied electromotive force and constant alternations. The secondary resistance may be in the windings themselves; or may be external to the windings, but part of the secondary body, or it may be entirely separate from the machine, and connected to the windings by the proper leads.

Fig. 6 shows the speed-torque curves for a motor with different resistance in the secondary circuit. In curve "a," the secondary resistance is small. In curve "b" the secondary resistance is doubled. The maximum torque remains the same, but the slip for any given torque is doubled. This motor starts much better than that in curve "a." In curve "c," the resistance is again doubled, and the slip is also doubled. The starting torque is increased, but the slip is rather large at the rated torque, T. In curve "d," the slip is again doubled. In this case the torque is high at start and falls rapidly as the speed increases. In curve "e," the maximum torque is not yet reached at zero-speed. Continuing these curves below the zero-speed line, that is, running the motor in the reverse direction, we get the general form of these different speed-torque curves. They are all of the same general shape, and all have the same maximum torque.

So far as torque is concerned, curve "d" is the best for starting. But for running, curve "a" gives the least drop in speed. Consequently, if a resistance is introduced at start that will give the speed-torque curve "d," it should be cut out or short-circuited for the running condition. This is one method of operation that has been much used.

Current Curve.—In determining the best starting condition, the current supplied to the primary must be considered in connection with the speed-torque curves. This current is plotted with the series of speed-torque curves shown in Fig. 6. Referring to this figure, curve "A" represents the primary amperes in terms of torque. Starting at the point "B," of no-load, or zero, torque, it rises at a nearly uniform rate until maximum torque is approached; that is, below the point of maximum torque the current is nearly proportional to the torque, but beyond this point the current continues to increase, and reaches a maximum at the torque represented by zero speed. At reversed speed this current is further increased. This one current curve holds true for all the speed-torque curves, a, b, c, d, etc.

Comparing the different curves, we see that "a" takes the most current at start, and gives low torque; "b" takes less current than "a," and gives more torque; "c" takes less current than "b;" "d" takes less current than "c," and gives the maximum torque at start, "e" takes less current than "d," and develops less torque; but the current and torque are very nearly in proportion over the whole range. From this we see that a speed-torque curve of the form of "d" or "e" is decidedly better for starting than "a" or "b." But for running at less than the maximum torque there is no advantage, so far as current is concerned, in curve "d" over curve "a," and the speed regulation of "d" is poor.



1-H.P. 3-PHASE INDUCTION MOTOR

Starting With Variable Secondary Resistance.—Fig. 7 represents the conditions of speed, current, etc., when a variable secondary resistance is used at start. The motor starts at "f" on curve "d," and takes a current "g." The current falls to "h," while the

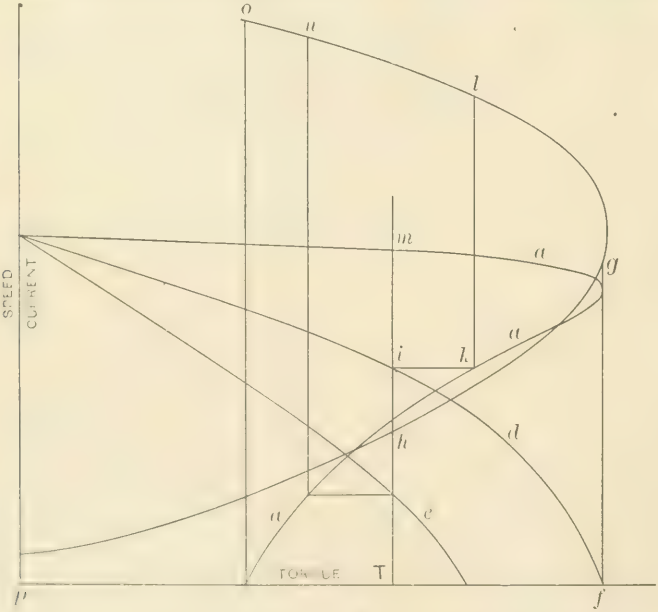


FIG. 7

speed rises to "i," which corresponds to the normal torque "T" at which the motor will run under the given conditions as long as the motor operates on curve "d." The speed will remain at this point. If the resistance in the secondary is now short-circuited, and the load thus shifted to the speed-torque curve "a," the torque at the speed "i" increases to "k" on torque curve "a." The current corresponding to this is "l." As the torque at "k" is greater than the normal torque "T," the motor speed will increase until normal torque is reached again at "m," while the current falls from "l" to "h."

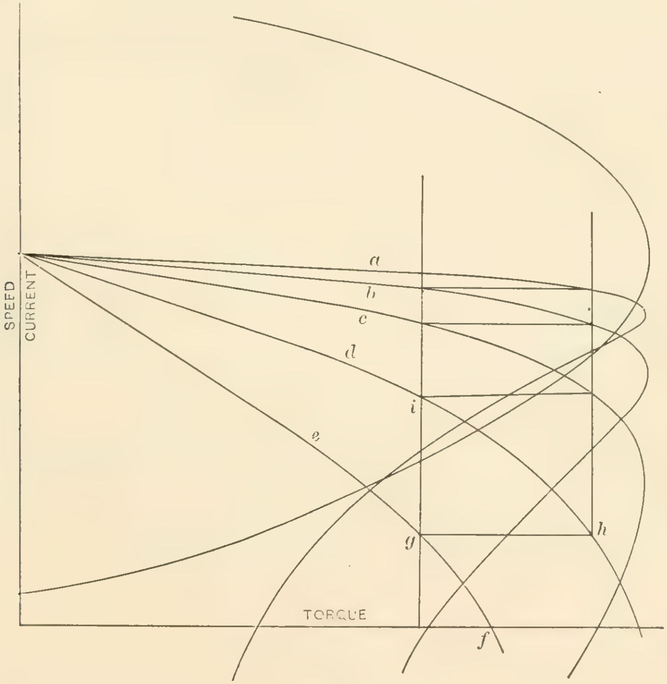


FIG. 8

At the moment of cutting out the secondary resistance, there will be a very considerable increase in the current. By arranging the starting resistance in the secondary so that the motor will start on some curve intermediate between "a" and "d," and thus take more current at start, somewhat less would be required upon switching curve to "a." If curve "e" is used for starting, and if the torque required when speeding up is greater than that at the point where curves "a" and "e" cross each other, the motor will not pull up.

because in switching from "e" to "a," the torque falls, and the motor will stop. The current on switching over increases to "n," and then rises to "o" as the motor stops. In this case the resistance that gives curve "e" is too great, and a lower starting resistance is required. With a large number of resistance steps, small variation of current is secured. By making several steps of the secondary resistance, so that it may be cut out gradually, the motor may be made to pass through a series of speed-torque curves with much smaller variations of current than shown in the preceding diagrams. This method has been used to some extent, but requires collector rings or a complicated switching arrangement in connection with the motor secondary.

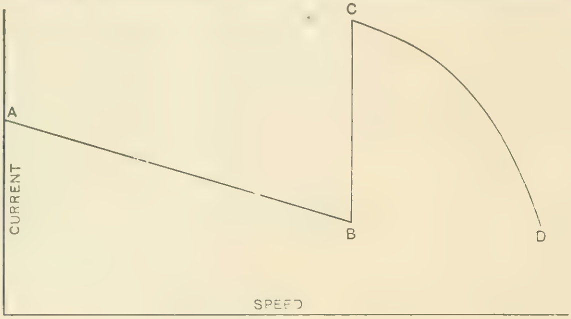


FIG. 9

Fig. 8 shows the conditions for starting and speeding up with five speed-torque curves. The motor starts on curve "e" at "f." The speed rises to "g." The motor is then switched to curve "d," the torque rising to "h." The speed then rises to "i." In this way the motor passes successively from "d" to "c," "b" and "a," until the full speed is reached. The currents at no time reach very high values.

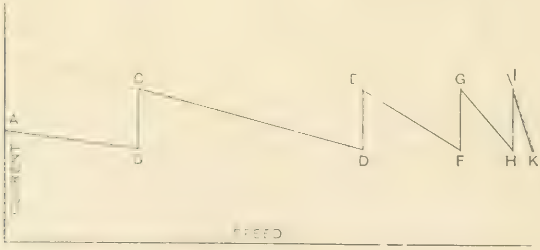


FIG. 10

Plotting the current in terms of speed, the use of a large number of steps is shown to better advantage. This is shown in Figs. 9 and 10. Fig. 9 shows the same starting conditions as Fig. 7 with curves "d" and "a." The current starts at "a" and falls to "b." The resistance is then short-circuited and the current rises to "c" and then falls to "d," which is the same as "b." If "a" had been higher at start, "c" would have been lowered slightly. But as the time required for passing from "a" to "b" is generally greater than that from "c" to "d," "c" may be higher than "a." If the motor is not required to develop such a large torque when pulling up, then "c" may be lowered, while "a" is left unchanged.

In Fig. 10, the currents in terms of speed are shown for five steps with the five speed-torque curves of Fig. 8. The starting current "a" is low, and none of the currents, when switching from one curve to another, is large. The dotted lines show the corresponding currents for two steps, as in Fig. 9.

(TO BE CONCLUDED IN OCTOBER)

CROSSING A RAILROAD RIGHT OF WAY BY A TRANSMISSION LINE

By P. M. LINCOLN

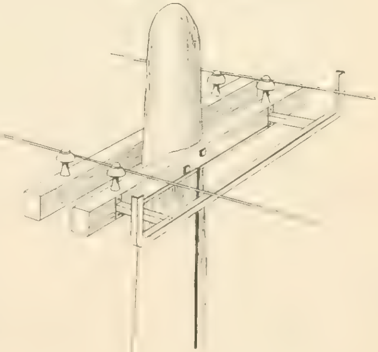
WHERE a transmission line crosses a railroad right of way, the railroad being the older enterprise, will impose certain conditions to be met by the transmission company in order to secure safety to the railroad's traffic. It may be that an underground crossing will be prescribed, or it may be an overhead crossing of a more secure nature, and of both of these I will briefly speak.

In conveying cables underground, in the present state of the art, line construction above 20,000 volts is an impossibility. Even at this voltage it is a very difficult requirement for the transmission company to meet. There are but two places that I know of where so high a pressure as 20,000 volts is in use on underground cable sections. It is also to be noted that while the influence of short sections of cable on long aerial lines is at present unknown, it is more than likely that experience will develop the fact that the protection of these short lengths is more difficult than the protection of an entire underground system at the same voltage.

The only way, therefore, in which potentials over 20,000 can be carried underground, is to make an opening under the right of way, of sufficient size to permit aerial construction in practically the same manner as it is now carried on the poles, except of course that the height need not be so great and the dimensions between the wires might be somewhat reduced. At the present time, therefore, a ruling by a railroad company, that no transmission lines should cross its right of way overhead, would practically exclude all transmission lines above 20,000 volts, and make it impossible for them to cross with their wires.

I take it that there are two distinct dangers which menace the railroad company's property at the point of crossing high-tension lines, one of which is electrical and the other mechanical. The electrical danger obtains whenever the wire comes near enough to the ground, or to trains passing under them, that persons on the right of way or on the trains can by any means come in contact with them. The mechanical danger is due to the transmission cables getting across the tracks or in the way of the trains and is entirely independent of the danger from shock. So long as the cables can be kept a safe distance from the ground, say 30 feet, neither of these dangers will exist. It is only when the cables come down either partially or completely that there will be any danger to a railroad company's traffic.

The question, therefore, resolves itself into this: How can the cables of the transmission company best be kept in place, and should they by any means break, how can the electrical charge be removed from them at that time? The best possible mechanical construction, it seems to me, consists of the transmission cables alone, provided they are properly put up. Any structure, such as a net, placed upon the same poles, is bound to throw an additional mechanical strain upon the structure with the result that as a whole it is weakened and not so able to bear abnormal mechanical strains as the transmission cable alone. In other words, the best bridge that can be put across the right of way over which the transmission company is to send its power, consists of the transmission cables themselves and any additional mechanical devices hung upon this structure must necessarily tend to weaken the structure and thus defeat its own purpose. Mechanically, therefore, the transmission line alone is the best construction. In making this statement, I do not refer to the mechanical construction which is typically represented by the average telegraph line. The telegraph line built usually of a small solid conductor strung very tight, when coated with snow or ice has not nearly so large a factor of safety, particularly as that of a transmission line when properly constructed. The transmission line conductors are usually of large cross-section, are stranded and therefore have an ample factor of safety, even though coated with ice. The only dangerous feature, which first-class mechanical construction does not reduce to a minimum, occurs then, and then only, when the transmission line comes down on the right of way of the railroad company with the electrical charge still upon it. A very effective method of



overcoming this difficulty is readily suggested by the accompanying sketch. The idea is to place on each adjacent pole a grounded metallic arm to reach some distance out from the pole and come close up underneath the wires of the transmission line in such a manner that should a wire break at the right of way, or should it suddenly sag, it will come in contact with the metal arm and be thereby grounded.

In order to obtain the best mechanical construction, it would be well to adopt the following specifications covering the span which crosses the railroad right of way as well as the three or four adjacent spans on either side.

1st. The distance from the top of the rail to the lowest point of the transmission line shall in no case be less than 30 feet. This specification need only apply to the right of way spans and need not necessarily apply to the adjacent spans.

2d. In no case shall the size of the conductor which crosses the right of way be less than 1-10 inch in cross-section.

3d. The form of the conductor shall be that of a stranded cable, the number of strands being at least 19.

4th. Only sound poles shall be used in this construction and they shall have a top diameter of at least 9 inches.

5th. The two poles adjacent to the right of way shall be braced in such a way as to make it impossible for them to fall toward the tracks.

6th. Two poles adjacent to the right of way shall be provided with double cross arms and the transmission lines fastened to the insulators in such a way that it will be impossible for the transmission line to slip through.

The proper way to handle this problem, therefore, is to insist upon first-class mechanical construction of the pole line at the point where it crosses the railroad company's right of way, and to take the further precaution of putting up the grounded metallic arms.

OPERATION OF THE SERIES TRANSFORMER

By EDWARD L. WILDER

THE field of usefulness of the series transformer is rather narrow as compared with the shunt transformer, and probably for this reason its methods of operation are not so generally understood.

The principal difference between the series and the shunt is, as the name indicates, in the connection in the circuit; the one having its primary in series with the line, while the other has its primary shunted across the line. The primary current, then, in the series transformer, is the quantity which is determined by the condition of the main circuit, the primary e.m.f. being merely the drop across the transformer due to its impedance. In the shunt transformer, the primary e.m.f. is the quantity which is determined by the main circuit, the primary current being determined by the impedance of the transformer.

Consider the case of a series transformer with its primary coil connected in the line and its secondary coil on open-circuit. The primary current, which is also the line current, will set up a magnetic field in the iron of the transformer, which, by self-induction, will cause a certain drop in voltage across the primary coil. The same magnetic flux will also cut the secondary turns and generate in them an e.m.f. whose value is equal to the voltage drop across the primary coil multiplied by the ratio of secondary to primary turns, just as with a shunt transformer. When the secondary coil is open-circuited all of the primary current is effective in producing flux, i. e., there is no opposing flux as there is when there is a secondary current. For this reason the iron of the transformer is worked at a high degree of saturation when the secondary is open-circuited, which gives an abnormally large secondary voltage. In the case of a 10 to ½-ampere series transformer, the test of which is given later, this secondary voltage was approximately 4,000 volts. This clearly brings out the reason why the series transformer should never have its secondary open-circuited when current is flowing in the primary.

Now, suppose the secondary circuit to be closed through some resistance. The primary current and magnetic flux are not changed but a secondary current will begin to flow in such a direction that the magnetic flux set up by it will oppose the primary flux. This will cause a decrease in the resultant flux present in the iron and consequently in the secondary and primary e.m.f's. The secondary current will continue to increase and the secondary e.m.f. to decrease until a stable condition is reached where the secondary e.m.f. is just great enough to cause the secondary current to continue to flow. This adjustment between secondary current and secondary e.m.f. takes place instantaneously. The resistance in the secondary circuit is low under ordinary conditions of working, so that the necessary secondary e.m.f is correspondingly small and the resultant magnetic flux required to generate this e.m.f is small.

If no magnetizing current were required, the secondary ampere-turns would exactly balance the primary ampere-turns and consequently the ratio of the primary to the secondary current would be the inverse ratio of the number of turns. To cause the current to have this ratio as nearly as possible the iron is worked at a low magnetic density so that very little magnetizing force is required. The series transformer is worked at about one-tenth the magnetic density of the shunt transformer, which is the reason why an ordinary shunt transformer would not be suitable for use as a series transformer.

If the line current and, therefore, the primary current increases, the primary ampere-turns are correspondingly increased. This leaves a greater difference between the primary and secondary ampere-turns. This causes a greater magnetic flux, which in turn increases the secondary e.m.f., and as the secondary current increases in response it reacts upon the magnetic circuit to decrease the flux. A stable condition will again be reached when the secondary e.m.f. is just sufficient to circulate the secondary current. The ratio between the primary and secondary currents will remain practically the same as before, because of the small extra magnetizing force necessary. There is a greater resultant magnetizing force necessary when the primary current increases on account of the greater secondary e.m.f. required by the greater secondary current.

A change in the secondary resistance causes a similar change in conditions; when the secondary resistance is increased this momentarily decreases the secondary current which allows a larger resultant flux, which in turn increases the secondary e.m.f, which increases the secondary current. When a stable condition is reached there is a greater secondary e.m.f. and a slightly less secondary current. An increase in the secondary resistance does not mean a proportionate decrease in the secondary current as would be the case in a constant voltage circuit; it means only such a decrease in the current that the resulting increase in magnetic flux and in secondary e.m.f. will be great enough to circulate the current through the increased resistance.

The fact that the current ratio is not appreciably affected by changes, within limits, in the secondary resistance and primary current, is due to two reasons: first, that the magnetization throughout the range of working conditions is small; and, second, that the magnetizing current is not in phase with the primary or the secondary currents, being nearly in quadrature with both. The exact relations of these quantities may best be shown by means of a vector diagram.

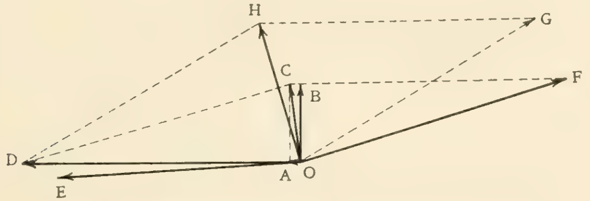


FIG. 1—VECTOR DIAGRAM OF SERIES TRANSFORMER

In Fig. 1, assume for the sake of simplicity, a transformer with one primary and one secondary turn. Current vectors then will also represent magnetizing force in ampere-turns. The secondary current is supposed to be closed through a low resistance. In Fig. 1 let *OD* represent a constant primary current. The primary drop will be a little in advance of *OD* and is represented by *DE*. *OF* represents the secondary current which is nearly 180 degrees behind *OD*.

The magnetic force which sets up the flux in the magnetic circuit is the resultant of the primary and secondary ampere-turns, and will, therefore, be represented in the diagram by *OC*, the resultant of *OD* and *OF*.

OC, which is ordinarily called the magnetizing current of the transformer, may be considered as broken up into two components, *OA* and *OB*, in phase and in quadrature with the e.m.f. respectively. *OA* represents the current necessary to supply the iron-losses and *OB* represents the true magnetizing current.

From the figure it is evident that the principal effect of the iron-loss is to change the current ratio, while the principal effect of the true magnetizing current is to shift the phase position of the secondary current.

This furnishes the explanation of the fact that if the primary current is increased or the secondary resistance increased the current ratio is affected. Both of the changes result in an increased secondary e.m.f., which requires a greater flux. This causes a greater iron-loss as well as necessitating a greater magnetizing current, both of which change the current ratio.

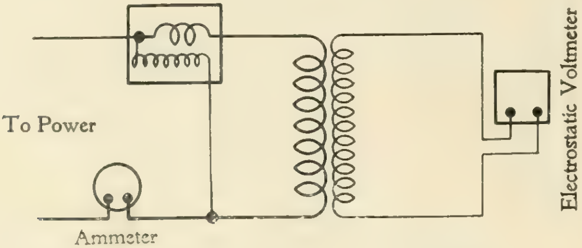


FIG. 2—CONNECTIONS FOR SERIES TRANSFORMER TEST

As an illustration of the relative magnitudes of the quantities involved in Fig 1, the results of the test of 10 to ½-ampere series transformer are given. The diagram of connections is given in Fig. 2. With the secondary on open-current, the primary current and watts were observed for various values of secondary voltage, which were read by means of an electrostatic voltmeter. What was measured, then, was the magnetizing current and its energy component, *OC* and *OA* in Fig. 1. The results of the tests are shown in Fig. 3. Assuming full-load current in the primary, the secondary current may be determined for any given secondary resistance by calculating what secondary voltage is necessary to give one-half an ampere with this resistance, finding the corresponding magnetizing current, and making a construction similar to Fig. 1. The primary voltage and current may be considered to be in phase as they differ in this case by only a fraction of one degree. If in any case the secondary current differs much from the assumed value of one-half ampere, the secondary voltage may be corrected accordingly and another construction made.

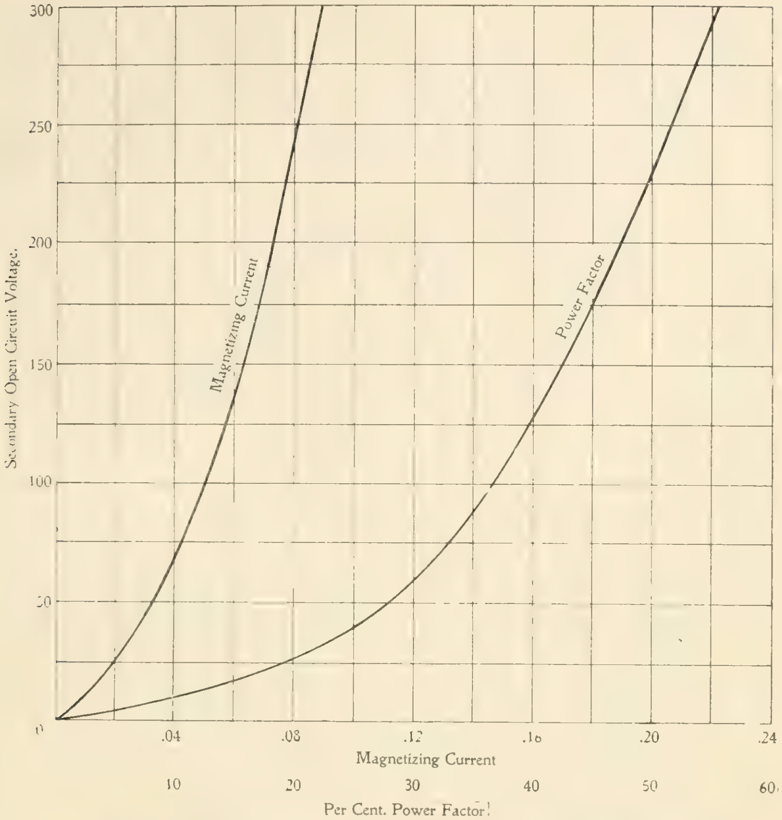


FIG. 3—IRON-LOSS AND SATURATION TEST OF A SERIES TRANSFORMER

The following table was calculated in the manner indicated. Ten to one-half ampere series transformer, 60 cycles. Secondary internal resistance 100 ohms.

Secondary External Resistance in Ohms	Primary Current Amperes	Secondary Current Amperes
0	10	.498
100	10	.489
200	10	.480
300	10	.474
400	10	.467
500	10	.461

This transformer was designed for a high variable secondary resistance, the maximum resistance being 400 ohms. This is an unusually severe condition to meet, series transformers ordinarily working with about 10 ohms secondary resistance.

SOME EXPERIENCES IN BALLOONING

By R. WIKANDER

A Lecture Delivered before the ELECTRIC CLUB

AERIAL NAVIGATION has long been a fascinating problem, for which innumerable solutions have been proposed. Some inventors have designed machines *heavier than air*, using wings or propellers to produce movement in both vertical and horizontal directions in a manner similar to the flying of birds, while others, imitating the swimming of fish, have designed apparatus *lighter than air*.

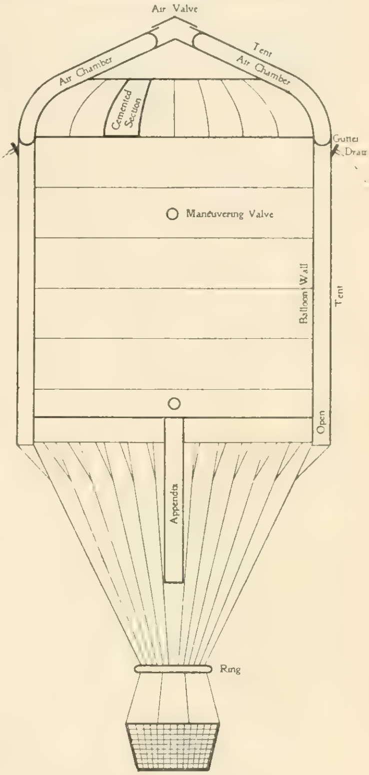
Though many inventors have constructed flying machines which exactly imitate the movements of the birds, no apparatus yet built on that principle has given satisfactory results, and of apparatus lighter than air, the balloon up to the present day is the only one which can be operated with any degree of reliability.

I propose in this paper to give some account of what has been done in ballooning, to recount some of my own observations and experiences, and in particular to recount a most thrilling escape.

The balloon was invented in the year 1783 by two brothers, Joseph and Etienne Montgolfier, at Annonay, France. They used hot air as the lifting power and kept the interior of the balloon warm by a fire suspended underneath. The same year, Charles, Professor of Natural Science in Paris, designed a balloon to be filled with hydrogen, or any gas lighter than air. With balloons of this design thousands of ascensions have been made, and yet to-day, 120 years after Charles designed his balloon, it is still the standard type.

It consists of a large spherical gas-bag, made of a material more or less airtight, and to be filled with hydrogen or coal-gas. This bag is completely enclosed in a network, which in turn supports the car. Near the top of the bag is a valve allowing the gas to escape whenever this is desirable. At the bottom an elongation called the appendix, through which the balloon is filled, is left open to act as a safety valve. Through this appendix the gas escapes when the pressure increases too much in the interior.

During the past 120 years it has been discovered how to make better cotton and silk fabric and better varnishes; also stronger and lighter ropes, and nicer wicker-work for the cars; but the design of aerostat that any balloonmaker will propose is still the same as in the days of Charles. The great number of aeronautical inventions made since that time refer almost entirely to the steerable balloons, and it is astonishing that the simple balloon, with all its weak points, was not improved upon to any considerable degree until a few years ago, when the Swedish captain, Eric Unge, invented a balloon which embodied some radical improvements. The aim of Captain Unge was to design a balloon that should be safer and able to float in the atmosphere for a considerably longer time than the ordinary type. It is a striking fact that no aeronaut has ever been able to keep his balloon floating in the air more than 36 hours, though it is quite possible to carry a quantity of ballast corresponding to the losses through leakage of the gas for more than a month. The reasons that ordinary balloons lose their buoyancy so rapidly are as follows:



(1) *Changes in the temperature of the gas,* principally due to the influence of the sun.

(2) *Moisture in the atmosphere,* especially rain.

(3) *Sudden movements in a vertical direction.*

(4) *The open appendix.*

(5) *The leakage through the bag,* especially through the seams.

All of these losses are diminished by the design of Captain Unge. The body of the balloon consists of plane, cylindrical and conical surfaces, made by long and wide pieces of cloth, so that the lengths of the joints and the corresponding leakage is reduced about 75 per cent. (Andres' balloon had about ten miles of seams.) One section of about thirty square feet in the top cone is merely cemented so that it can be readily torn off by means of a cord running down to the car. This allows the balloon to empty.

In order to prevent a rapid descent of the balloon, in case of an accident, the car is suspended by ropes attached to a special width of a very strong canvas, which runs around the base of the cylinder. With this arrangement, the bottom of the bag forms a parachute which at once opens with rapid descent.

A safety valve is located near the bottom of the gas cylinder through which the gas escapes if the interior pressure should become too great. This allows the appendix to be kept closed. The diagram shows this balloon provided with a protecting tent of white, waterproof muslin. This tent is held about one foot from the gas bag, by means of air-chambers. At the top of the tent there is a valve which can be closed or opened from the car. The maneuvering valve is located in the side of the cylinder near the top.

Comparing this design with that of the ordinary balloon it will be seen how the different losses are decreased.

(1) The temperature changes of the gas, principally those due to the influence of the sun, are the most important causes of the gas and ballast losses. If the sun is shining on a balloon floating in the air, it raises the temperature of the bag and of the gas considerably above that of the surrounding air. Differences of more than 60 degrees C. have been recorded. This may correspond to an increase of 20 per cent. in the lifting power of the gas. In order to maintain equilibrium, the same per cent. of gas must be allowed to escape. When night comes, the gas cools, taking the temperature of the surrounding air or a slightly lower one, and it is necessary to throw out a quantity of ballast, corresponding to the decrease in lifting power of the gas. This is repeated in a less prominent degree each time the balloon is subjected to temperature changes, as when a cloud passes over the sun or when the balloon passes over an open field to a forest, which latter does not reflect so much heat as the field.

With the Unge design, the protecting tent is made of shining white rainproof muslin, which reflects the sun's rays. What heat is absorbed by the tent will first warm the air between the tent and the gas-bag and the air will ascend and escape through the valve at the top of the tent, while the surrounding cold air enters at the bottom. If in such a case it should be desired to raise the balloon, this can be done simply by closing the air valve at the top, retaining this heat in the balloon. In the case of the ordinary balloon, the rain will make the net work and the gas-bag wet and heavy. To compensate for this added weight a considerable amount of ballast must be sacrificed, often as much as 200 pounds for a balloon of medium size.

With the Unge balloon, the rain will run off from the conical top and accumulate in a gutter which is provided with many projecting rain spouts. Practically no rain will fall on the sides of the tent, as the balloon moves horizontally at the same speed as the wind. The ballast losses through rain will therefore be greatly diminished.

The author made the acquaintance of the late Captain Unge in Paris at the time of the Aeronautical Congress in 1900 and soon afterward became his assistant in working out several aerial inventions. The first of them was the balloon above described. As soon as it was patented, we went to Stockholm, where the Captain delivered a lecture on his balloon before the Aeronautical Society of Sweden. Two weeks afterwards that society ordered the first balloon of this type. The author was charged with its construction and built the balloon at the Continental Caoutchouc and Guttapercha Company at Hanover. The gas-bag was made of double cotton fabric, covered and cemented with ten layers of finest para rubber solution. The tent was made of shining white rainproof muslin. In two months the balloon was ready and in July, 1902, I brought it to Stockholm. Six days later the first ascension was made by Captain Unge and two members of the Aeronautical Society. The filling and the starting presented no difficulties. The balloon took its way out over the Baltic, much to the surprise of all spectators.

Two days later a telegram announced its safe landing in Russia, not far from Old Novgorod. The crossing of the Baltic was made without mishap and the ballast losses were exceedingly small. The aeronauts decided to descend after 24 hours, the weather being very foggy, and their exact location uncertain, though they supposed themselves moving toward the northern part of Russia. The descent was made in a forest without accident, though the wind was very strong.

After two weeks, the balloon was brought back and at once preparations were begun for a second trip. This time Captain Unge and myself were the only passengers. A great crowd assembled to see the start and even our old King came down to wish us good luck. The wind was very light, the sky clear, and more delightful weather could not have been desired.

At 4:30 p. m. we left the ground with a rather great ascensional power; at first slowly, then faster and faster, up into a brilliant sunlight. A view splendid beyond description presented itself. Sport Park, from which we had started, appeared smaller and smaller. Stockholm, the Venice of the North, with its harbor and many islands lay underneath. To the east was the Skargard, with its thousands of islands filling the water-ways from the Baltic to Stockholm. To the west the beautiful Lake Malar, with its many bays and islands. Immediately I set about to take a picture, but had hardly begun to adjust my camera when Captain Unge, who was maneuvering the balloon, suggested that I put up my camera and pay attention to the balloon. The gas-bag, which at the start was only filled to about 95 per cent. and closed at the bottom, filled itself more and more, indicating that we were ascending rapidly. Some gas was allowed to escape, nevertheless we continued ascending, the bag filling more and more. Soon the gas came down in the appendix. I went up in the ring and opened it, the gas escaping with greater velocity. We were now over a mile above Stockholm, when suddenly the appendix became flat and empty. The balloon had exploded in plain sight of the whole city. I went down in the car while the balloon fell some hundred feet. We loosened the ballast. Then I looked up and saw how the bottom of the gas-bag had formed an ideal parachute as had been intended, but we were descending rapidly. Looking down we saw the many islands in and around Stockholm as a great number of black spots, the size of which increased even as we looked upon them. The sensation was much as if the balloon were stationary and the earth coming nearer—as if everything was growing larger and larger.

Then a big island came rushing toward us with increasing speed. At first it appeared to be a flat surface covered with moss, then the moss became a bush, the bushes grew into trees and from the middle of the island a mountain arose. The mountain and the trees grew larger and larger and soon we saw them at a distance of about 200 feet rapidly approaching. I went up in the ring in order to let the car take the first shock. The captain held the ladder in his hand, but did not mount. When I was half way up I heard a great crash as the car broke through the branches of the trees, and an instant later stopped on a rock. I came down from the ring, I don't know how, but found myself on the ground a few yards from the car. I was rather surprised not to have broken any bones nor to have been otherwise injured. Going to the car, I found it thrown on one side. The Captain, with all our stores, was lying at the bottom of the car, but quite uninjured. In a short time the forest was crowded with people. One of the first who welcomed us back was an American reporter, who said: "Mr. Wikander, may I grasp your hand! I am going to cable to America; tell me all about it."

The great drawback of the simple balloon is that it must follow the winds. This, however, will not be such a great inconvenience when we know more about the air currents at different heights. It is a fact that the direction of the wind changes considerably with the altitude to a certain degree.

In order to secure perfect control of the balloon it is, however, necessary to provide it with motor-driven propellers, wings, or some means of propulsion. The first successful balloon of this type was built 20 years ago by the French officers, Renard and Krebs, at Chalais, near Paris. Their balloon had a cigar-shaped gas-bag supporting a long car, equipped with a storage battery, an electric motor and a propeller. With this balloon seven trips were made. On five of these the balloon returned to the starting point without mishaps. On one trip the motor broke down, and once the wind was stronger than the propelling power of the balloon. The highest speed attained by this balloon was 14½ miles an hour in a calm.

A few years ago a German, Count Zeppelin, built a great cylindrical balloon. The main body was a rigid framework holding 17 silk balloons. To give it a smooth surface the whole balloon was covered with muslin. This balloon had the bulk of a trans-Atlantic steamer, and held about 300,000 cubic feet of hydrogen. It made several ascensions with fairly good results attaining a maximum speed of about 18 miles per hour. Since 1897 a Brazilian, Mr. Santos-Dumont, has made experiments in Paris with several dirigible balloons. With these he has made many trips around Paris in fair weather, and with one of them he won the prize Deutsch of 100,000 francs. The greatest speed he has obtained is about 18½ miles per hour. The best results ever obtained with dirigible balloons must, however, be credited to the balloon of the Lebaudy brothers, two French millionaires. The general plan of the balloon does not differ very much from the design of Renard and Santos-Dumont, but it shows several interesting details. The whole makes the impression of skillful mechanical design. The maximum speed obtained is 25 miles per hour, and the greatest distance is about 62 miles. Twenty-nine ascensions have been made.

POWER-FACTOR METERS AND THEIR APPLICATION

By PAUL MacGAHAN

IN the July number of THE ELECTRIC CLUB JOURNAL there appeared a contribution on the subject of connections of power-factor meters, which has brought out requests for fuller information concerning this interesting instrument.

The demand has long been insistent for a simple, direct-reading instrument which would indicate on a dial the power-factor of the circuit to which it is connected in as satisfactory a manner as an ammeter indicates the amperes. Though many different arrangements have been proposed, especially in Europe, all of them have been laboratory devices not suitable for commercial work or for use on a power plant switchboard.

In operating alternators or rotary converters in parallel, a power-factor meter enables the attendant to divide the load properly between the units, or to adjust the field current so as to obtain the maximum power-factor in the line and thus the lowest possible line loss. In an industrial plant using induction motors, the power-factor meter will indicate whether the motors are being used under the best conditions of load, and the relative power-factors of different motors.

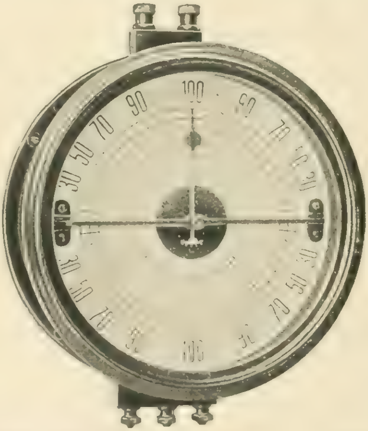


FIG. 1—SWITCHBOARD TYPE OF POWER-FACTOR METER

It is often found, in switchboard design, that one power-factor meter can be used to advantage instead of two or three ammeters, and in connection with a wattmeter give all the quantities it is necessary to know. The number of instruments on the panel can thus be reduced.

The power-factor meter is unique among instruments in that it does not indicate a quantity in the ordinary sense, but an angle.

Thus it has no "controlling force" such as a spring, or a weight, but the pointer varies its position with the angle between the current and the voltage, throughout the circumference of the scale.

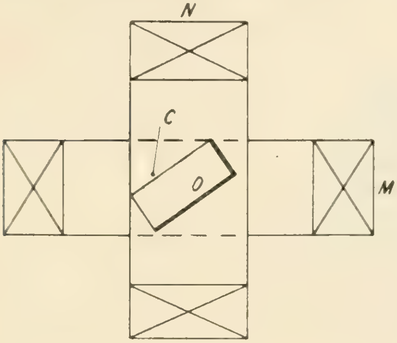


FIG. 2

The scale is marked in cosines of the angle between the points so marked and the vertical. This is shown by Fig. 1.

The principle and construction of the instrument is as follows:

N and *M*, Fig. 2, are two coils arranged at right angles to one another. Through the coil *N* passes a current which is in phase with the current of one phase of the circuit to be measured. Through the coil *M* passes a current which is 90 degrees out of phase with that in coil *N*. With a two-phase circuit the coil *N* would be connected to one phase and the coil *M* to the other. In a three-phase circuit, three coils would be used, one to be connected to each phase. As the current in coil *N* will be maximum when that in coil *M* is zero, and vice versa, the field produced by these two coils will rotate with a speed which depends upon the frequency of the circuit to which they are connected. A small coil *C* is pivoted so that it can rotate and thus bring its axis in a line with coil *N* or *M*. Through this small coil passes a current in phase with the voltage of one phase of the circuit which is to be measured.

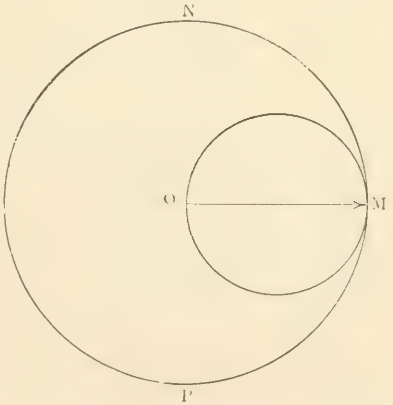


FIG. 3

In the direction *O-M* the field will be zero when the current in the coil *N* is zero, and in the direction *O-N* the field will be zero when the current in coil *N* is maximum. Thus between these two points a zero field can be found at any time between the maximum and zero of the current in the coil *N*.

As the small coil *C* will be attracted or repelled by the field of the coils *N* and *M* it will take up a position in which its zero field will occur at the same time as the zero of the rotating field. Thus, if the current in coil *C* is in phase with the current of the coil *N* it will take up a position with its axis in the line *OM*, while if the current in coil *C* is at quadrature with the current of the coil *N* it will take up a position with its axis in the line *ON*, and for any phase relation between these two it will take up the corresponding position between *ON* and *OM*. This may be shown graphically as follows:

In Fig. 3, *OM* is the field which rotates around in the plane *NMP*. The small movable coil is in the plane *NP*. Its field will therefore be in the direction *OM*. Its phase will coincide with that of the rotating field in the direction *OM* when the current in this coil is in phase with that in the coil N. Should the current in the coil *C* be shifted in phase an amount *MR* its phase will coincide with that of the rotating field at *OR* while its direction will remain in the line *OM*. (Fig. 4.)

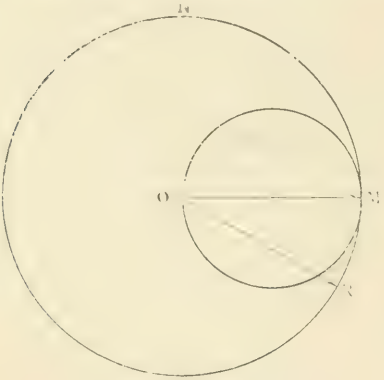


FIG. 4

When the field is rotating from *ON* to *OM* there will be a pull on the movable coil *C* tending to rotate it in the direction *OM* to *ON*. During the rotation from *M* to *P* there will be a pull on the coil in the opposite direction. This pull will be proportional to the product of the strength of the rotating field in the direction *ON* or *OP*, and that of the field due to coil *C* in the direction *OM*. The total pull between the time *N* and *P* will therefore be proportional to the area of a circle with a diameter equal to *OM*, and with its center on the line *OM*. The pull in the direction *MN* being proportional to the area of that part of the circle which is above the line representing the phase of the rotating field which coincides with that of the coil *C* and the pull in the direction *MP* will be proportional to the area of that part of the circle which is below this line.

In Fig. 3 is shown the condition in which the current in the coil *C* is in phase with the current of the coil *N*. The phase of the coil *C* coincides with that of the rotating field in the direction *OM*. Areas above and below the line *OM* are equal, and therefore the resultant pull on the coil *C* will be zero.

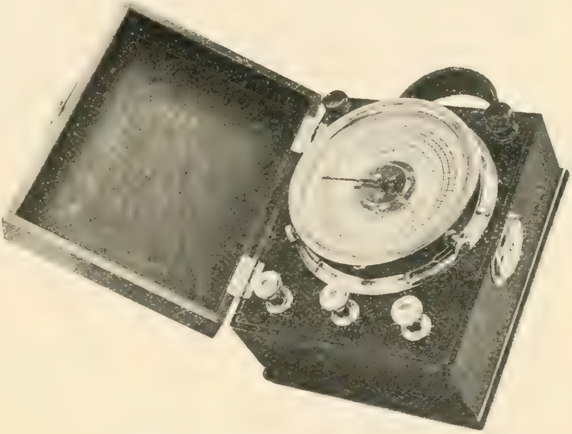


FIG. 5—PORTABLE TYPE OF POWER-FACTOR METER

In Fig. 4 the current in coil *C* is shifted in phase an amount *MR*. The phase of the current in coil *C* will thus correspond with that of the rotating field in the direction *OR*. As the area of the circle above *OR* is greater than that below there will be a resultant pull on the coil *C* which will tend to make the lines *OM* and *OR* coincide, thus moving the coil through an angle *OM* when the pull will again become zero.

The movable coil *C* will thus shift around to a position which corresponds to the angle between the current in coils *N* and *C*. Therefore, if a pointer were attached to this coil and moved over a scale graduated in degrees it would show the difference in degrees between the phase of these two currents. As actually constructed in this instrument the coil *C* is replaced by a movable piece of iron, this iron being magnetized by a stationary coil in a manner similar to the field in an inductor-type generator. This movable piece of iron performs the same functions as the movable coil and obviates the necessity of carrying current to a moving coil, thus simplifying the construction of the instrument.

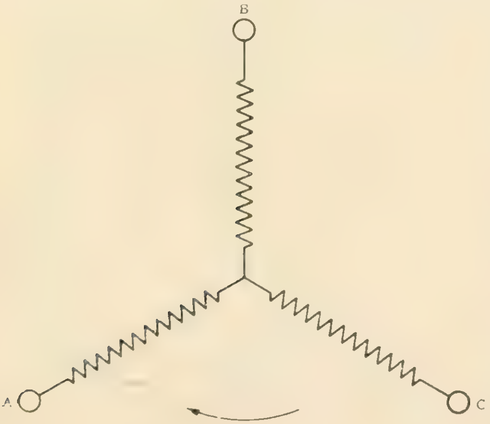


FIG. 6

Owing to the hysteresis losses in the movable iron needle, there is a tendency to rotation, produced by the rotary effect of the polyphase windings. The field of the voltage coil prevents this, for the reasons previously explained, but when the voltage binding posts are disconnected, and there is sufficient current in the field circuits connected to the lower binding posts, the pointer rotates. This effect is taken advantage of to check the connections of the instrument, for if the currents supplied are not of the proper phase relation, the pointer will either revolve in the wrong direction or will not revolve at all.

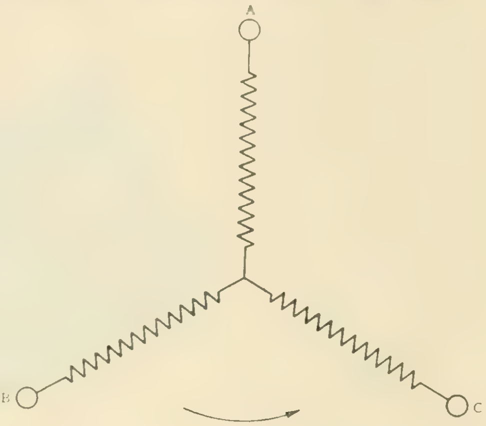


FIG. 7

In the following diagrams the external field coils are shown diagramatically 120 degrees apart.

If the "progression of the phases" in the lines is in the order *A, B, C,* and they are connected to the coils as shown in Fig. 6, the rotation will be in the direction indicated by the arrow. If, however, the phases are connected to the coils as shown in Fig. 7 (a pair of binding posts being reversed) the rotation will be in the opposite direction.

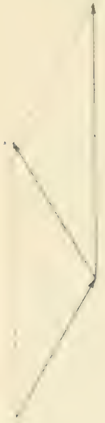


FIG. 8

Two series transformers being used, and their currents combined to form the third phase, a reversal of one series transformer will combine the currents according to Fig. 8, instead of Fig. 9, and the resultant current *C* will be 8.67 amperes instead of 5 amperes, when the currents in the secondaries of the transformers are 5 amperes.

In this case no rotation of the pointer will take place.

From the above discussion it will be appreciated how important it is to have the connections as shown in the diagrams and the coils within the instrument supplied with currents of the proper phase displacement.

When the top binding posts are disconnected and there is current of at least one-half full load in the series transformers, the pointer should rotate in the *lead* direction. If it rotates in the *lag* direction, the leads running to the lower left-hand binding posts should be reversed. On a two-phase circuit the reversal should be made at the series transformer shown on the left of the diagram. On a three-phase circuit the lead should be reversed at the meter by connecting the common wire from the two series transformers to the left-hand binding post, and the single wire from the series transformer on the left to the middle post. Then the shunt circuit to the upper binding posts should be connected as shown This shunt connection should be made to the phase which is connected through the series transformer to the right-hand side of the meter. Should it be necessary to reverse the series connection of the meter on three-phase circuits from that shown on the diagram in order to obtain proper rotation, the shunt wire which is shown connected to the wire of the circuit having no series transformer should be changed to the wire which is connected through the series transformer to the left-hand side of the meter. The upper half of the scale indicates for power delivered from alternating-current lines to the motor or converter, and the lower

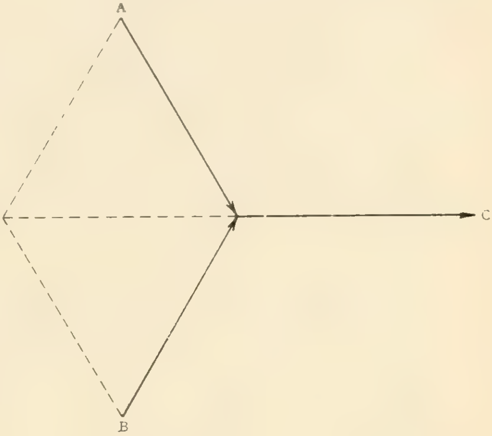


FIG. 9

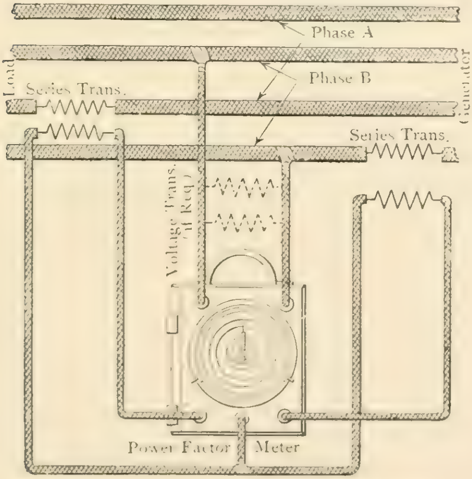


FIG. 10—PORTABLE POWER-FACTOR METER CONNECTIONS FOR A TWO PHASE CIRCUIT

half, power returned to the lines. Should the pointer indicate the reverse of that given above, the connection at the upper binding posts should be reversed.

The slight variation of this rotary effect with the frequency is the only frequency error to which the instrument is liable.

The instrument attains its highest accuracy when the current in the current coils is from 3 to 5 amperes, and the voltage on the voltage coil from 75 percent to 125 percent of the normal. Series and voltage transformers should therefore be of such a capacity as to give secondary values within the above limits as nearly as possible. They may be either of the ordinary switchboard or the portable type.

Within the above limits the instrument will indicate the true power-factor, within an error represented by an angle of two degrees deflection of the pointer from the true indication.

An ordinary unbalancing of the load on the phases has practically no effect upon the readings; a violent unbalancing, however, should be guarded against in taking very accurate measurements.

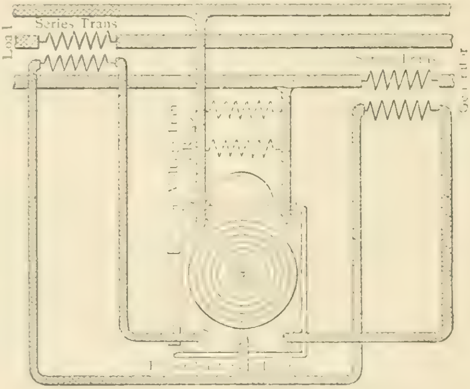


FIG. 11—PORTABLE POWER-FACTOR METER CONNECTIONS FOR A THREE PHASE CIRCUIT

The instrument measures the average angle of lag of the phases, and indicates the cosine of this angle; this is slightly different from the average power-factor of the circuit, but the difference is so small as to be negligible. Hence the instrument indicates a power factor based upon the average angle between currents and voltages in the polyphase circuit.

It should be noted, however, that the *true power-factor* is by definition the ratio between the real and the apparent watts as obtained from the ammeter, voltmeter and wattmeter readings, and not in all cases the cosine of the angle between the current and the voltage. When the waves are badly distorted the angle between the current wave and the voltage wave may be zero degrees, but still the power-factor may be less than unity.

When the left-hand binding post is disconnected the rotary effect disappears and the pointer therefore moves back slightly in a direction opposite to that of the rotation. This is made to serve as an index of whether the instrument has changed its calibration, for this resting point is marked on the scale in red ink during calibration, and, therefore, if the meter is still correct in calibration, the pointer will come to rest at this mark with current and voltage on and the left-hand binding post disconnected. Should the pointer not come to rest here, it should be shifted on the shaft until it does. Great care should be exercised, after this is done, to see that the movement is in perfect balance.

Owing to the manner in which the coils have to be wound, it is necessary in all cases to use series transformers with the power-factor meter. Two series transformers are sufficient for either two or three-phase instruments. In the latter case the third phase is formed at the binding posts by a combination of the other two phases.

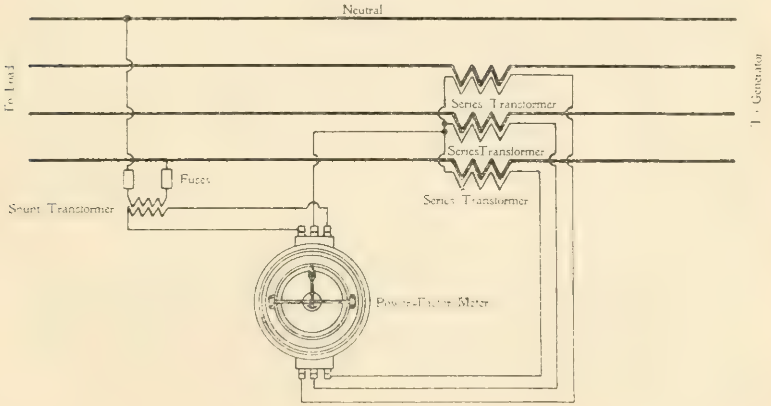


FIG. 12

In a four-wire, three-phase circuit, with the possibility of current passing through the neutral wire, an extra binding post is added to the instrument, and connected to the neutral point. Three series transformers are used in order to measure the current from each phase to the neutral, as in Fig. 12.

An ammeter may be so connected to the circuits of a three-phase power-factor meter, as to measure the current in any one of the three phases, as shown in Fig. 13.

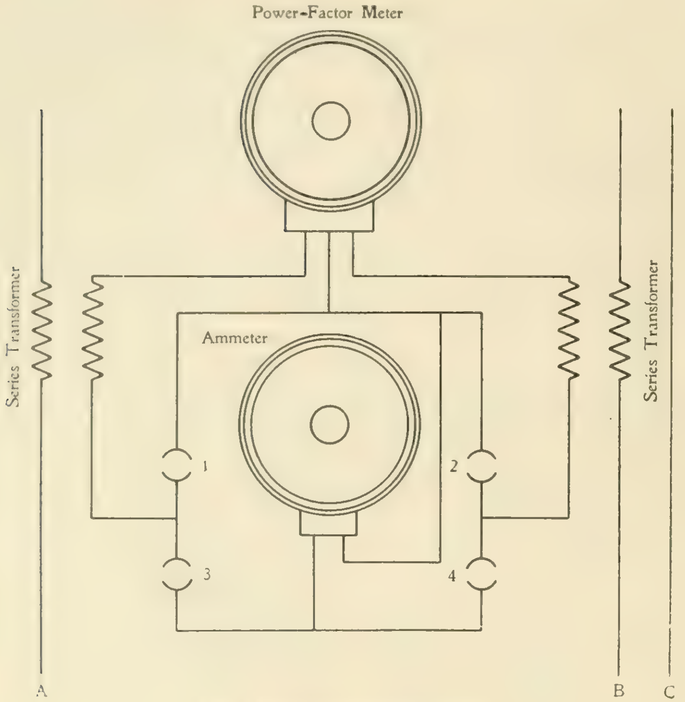


FIG. 13—POWER FACTOR METER

To read current in phase *A,* plugs 2 and 3 should be in.
To read current in phase *B,* plugs 1 and 4 should be in.
To read current in phase *C,* plugs 4 and 3 should be in.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

V—GENERATORS

By V. KARAPETOFF

A Series of Lectures Delivered before THE ELECTRIC CLUB

Equivalent Total Current and Resistance of Polyphase Machinery—In constructing a diagram for a single-phase alternator, motor, or transformer, there should be no confusion as to values of current and resistance to be used.

To avoid confusion in graphical investigations of polyphase machinery, it is advisable in every case, to reduce current and resistance to their equivalents for a single-phase machine having the same output, the same power-factor and the same percentage of internal drop, or, in other words, the same copper loss.

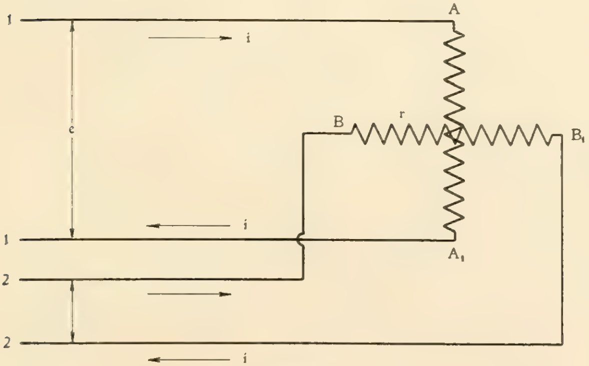


FIG. 41

(1.) *Two-Phase Machines.*—In a two-phase, four-wire system the outputs of both phases are simply added. If e is the voltage of a two-phase system, i the current per phase, and r the resistance per phase, (Fig. 41), all the diagrams must be constructed with the same voltage e, but with an equivalent current $I = 2i$ and an equivalent resistance $R = \frac{1}{2}r$, (since $I R$ must be equal to $2 \times i r$). The same applies, of course, to a two-phase three-wire system.

In some cases the scheme of connections shown in Fig. 42 is used for two-phase machines, as, for instance, in rotary converters and in some types of alternators. The resistance in this case is measured between the points A and A_1 and between B and B_1. Suppose this value is found to be r. Then the actual resistance of each leg AB or AB_1 will also be r, since two of such resistance are connected in series and two in parallel to make up the resistance from A to A_1, i. e., $\frac{1}{2}(2r) = r$. If the line current in each phase is i, the current in each winding of the machine is $\frac{i}{\sqrt{2}}$. The equivalent current, as in the previous case, is $I=2i$. Let the resistance of an equivalent single-phase machine be R. Then the condition, that there should be an equal copper loss in the actual two-phase machine and in the equivalent single-phase machine is,

$I^2R = 4\left(\frac{i}{\sqrt{2}}\right)^2 r$; and substituting $2i$ for I, $R = \frac{r}{2}$

Consequently, in this case also, the equivalent resistance R is equal to half the actual resistance, as measured between the terminals of each phase. Thus, whatever the scheme of connections inside a two-phase machine, the equivalent values of resistance and current are to be found by taking one-half of the resistance of a phase and double the current per phase.

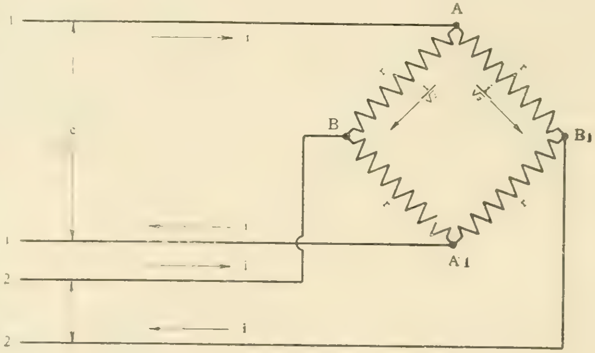


FIG. 42

(2.) *Three-Phase Machines.*—In the three-phase star connection of a machine, Fig. 43, the total output is $ei\sqrt{3}$, therefore the equivalent, or total current, is $I=i\sqrt{3}$. Let the resistance per phase of the winding be r. As the neutral point of a star winding is not generally accessible, the resistance is usually measured between two terminals as, for instance, between 1 and 2. In this case the measured re-

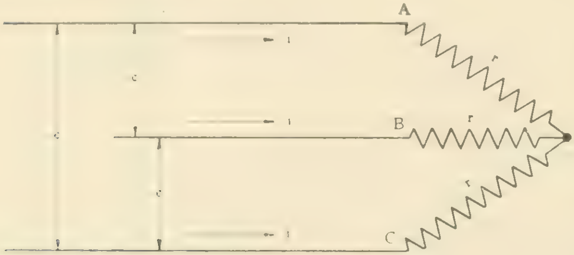


FIG. 43

sistance. r_1 is double the actual resistance per phase. Hence $r^1=2r$. Again supposing the copper loss of the machine to be equal to the copper loss of the equivalent single-phase machine, we get

$I^2R=3\,i^2\,r$ and since $I=i\sqrt{3}$ and $r=\frac{r^1}{2}$ we get by substitution

$R=\frac{r^1}{2}$ as in the previous case.

In a delta connected machine, Fig. 44, the equivalent current is again $I=i\sqrt{3}$ where i, is the line current. The current in each winding of the machine is $\frac{i}{\sqrt{3}}$. In measuring resistance between any two terminals, we measure a combination of the two resistances, r and r, in series and the resistance r in parallel with them. Therefore, the actually measured resistance is,

$$r^1=\frac{2rr}{2r+r}=\frac{2r}{3}$$

The equation of copper loss then is: $I^2R=\left(\frac{i}{\sqrt{3}}\right)^2r$,

so that in this case also, $R=\frac{r^1}{2}$

Thus, in any kind of two-phase or three-phase generator, transformer, motor, transmission line, or other apparatus, the equivalent resistance is one-half of the resistance measured from terminal to terminal.

To find the equivalent current, *i. e.*, the current in an equivalent single-phase machine giving the same output at the same voltage, and at the same power-factor, the current per phase must be multiplied by two, in the case of a two-phase system, and by $\sqrt{3}$ in the case of a three-phase system.

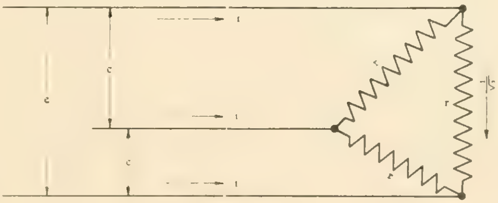


FIG. 44

In testing ordinary commercial polyphase machinery, neither voltages, currents, nor resistances are exactly the same in all the phases. There are always small differences and these necessitate the use of average values for the three quantities. Suppose the following values to have been found for a 2,200 volt three-phase generator.

	Volts.	Ohms.
Phase 1-2	2,201	1.883
Phase 2-3	2,197	1.911
Phase 3-1	2,202	1.894

The equivalent values for which any diagram should be constructed, are

$$\frac{2,204+2,197+2,202}{3}=2201 \text{ volts}$$

and

$$\frac{1.883+1.911+1.894}{6}=0.948 \text{ ohms.}$$

If this is a 100 kw generator, the equivalent full-load current at unit power-factor for a single-phase generator would be

$$\frac{100,000}{2,200}=45.5 \text{ amperes.}$$

FACTORY TESTING OF ELECTRICAL MACHINERY—VIII

By R. E. WORKMAN

THE SPEED OF A SERIES MOTOR—The speed at which any motor runs is such as to produce the counter e.m.f. necessary to allow the flow of just that amount of current which is sufficient to give a torque to the armature balancing that imposed on the motor by the load. Since the counter e.m.f. depends on the product of field strength and speed, if the field strength is increased the motor will be able to generate the necessary counter e.m.f. at a lower speed. Hence, in a series motor, in which the magnetizing force of the coils increases in direct proportion to the current in the armature, the speed falls very rapidly with an increase in the current. In fact, if the permeability of the iron in the magnetic circuit were constant, and if the effect of armature reaction could be neglected, the speed would vary inversely as the current. As the magnetic circuit becomes saturated, however, the speed falls less with a given increase in the current, corresponding to the smaller increase in magnetization. The curve of speed and current follows approximately the magnetization curve of the magnetic circuit, and, in fact, gives a good idea of the magnetic design of the machine.

In the case of a shunt or compound wound motor, an increase in temperature causes a decrease in the field current and field strength, which tends to raise the speed of the motor; at the same time, an increase in temperature, the armature current remaining constant, causes an increased ohmic drop in the armature, which tends to diminish the speed of the motor. In all ordinary cases the former effect is the controlling one and the speed of the motor increases with a rise in temperature.

In the case of the series motor, however, since the drop in the whole motor has to be supplied by a part of the terminal voltage and since this drop increases with the rise in temperature, the armature will not have so large a counter e.m.f. to induce when the motor is hot as when it is cold. It will be seen from this that the hotter a series motor is, the slower it will run at a given load.

As series motors are intended, as a rule, for intermittent service and are often run for considerable periods at heavy overloads and consequently attain a high temperature, the speeds found in the test are corrected to the values they would have at 75° C.

Speed Curves of Series Motors—*Preparations for Test*—The testing board shown in Fig. 12, page 171, in the April issue, is used. The motor to be tested is coupled to another series motor to act as load. The armature and field terminals of the motor to be tested are connected to A^1A^1, F^1F^1 respectively and those of the other machine to A^2A^2, F^2F^2 respectively. The power and load switch on the left is thrown to the power side and that on the right to the load side; the two switches IL^1 and IL^2 being open. A rack is put across L^1L^2 and plugged in to give a suitable load. The four switches, FS^1, AS^1, AS^2, FS^2 are closed and the motor started by means of a controller or a rheostat. The second machine will start up as a series generator and its load may be adjusted by changing the resistance in the rack.

Conduct of Test—The terminal voltage is held constant throughout the test by using the booster in series with the source of power and regulating the amount of resistance in its field. The current is varied by changing the load on the machine which acts as a generator. The readings to be taken are: terminal volts, amperes, field volts and speed. A series of such readings is taken within the workable range of speeds of the motor for both directions of rotation. It is usual to start the test with a heavy overload, say 100%, and to bring the load down gradually by convenient steps to as low a value as practicable. This insures a more nearly constant temperature during the test.

Precautions to be Observed—Care must be taken not to exceed the maximum safe speed of the motor; it is therefore important that there should be a part of the load rack plugged in before starting.

Working Up Results—The speed is to be plotted to the current in the ordinary way, but it is necessary to correct this speed for changes in temperature which have taken place in the various parts during the test. It is assumed that the armature and field resistance have already been found and their values are known at a temperature of 25° C. The equivalent values of these resistances at 75° C. are found by adding 0.38 percent to the resistance for every degree centigrade rise in temperature. Suppose the values thus found to be Ra for the armature winding and Rs for the series field winding. Knowing these values it is possible to calculate for any value of the current, the volts drop in the armature and series field at a temperature of 75° C.*

In order to find the volts drop in the motor for any current, under the conditions of the test (i. e., where the temperature is not necessarily 75° C.), it is simply necessary to multiply the observed drop across the series field winding by

$$\frac{\text{Total Resistance}}{\text{Field Resistance}} = \frac{Ra+Rs}{Rs}$$

This quantity is evidently constant for different temperatures, since for an increase in temperature the same percentage is added to both numerator and denominator. It is also evident that this is simply the ratio of the total drop in the motor for a given current, to that in the series field winding.

Example—The following is a sample reading on a No. 56, 500-volt railway motor, at 500 volts, right hand rotation:

Amperes	Observed Field Drop	Armature Field, Drop		Induced Volts		Speed	
		Observed	At 75° C.	Observed	At 75° C.	Observed	At 75° C.
150	24.6	44.5	47.5	455.5	452.5	430	427

Resistance of armature at 75° C. . . . . = 0.1418 ohm
Resistance of field at 75° C. . . . . = 0.1751 ohm
Resistance of armature + field at 75° C. . . . . = 0.3169 ohm

$$\frac{Ra+Rs}{Rs} = 1.81$$

The observed induced volts are found by subtracting the observed drop in the armature and series windings from the line volts. The induced volts for the same current at 75° C. are found in like manner from the drop in the armature and series windings, calculated from the known resistance of armature and field at 75° C. The speed at 75° C. will evidently bear the same ratio to the observed speed that the induced volts at 75° (or counter e.m.f. at 75° C.)

---

*On page 101, lines 27 and 28, of the March issue the constant 0.42 should be changed to 0.38 as given above; 0.42 is the percentage rise in resistance per degree centigrade with an initial temperature of 0 C, while 0.38 is the percentage rise in resistance per degree centigrade with an initial temperature of 25° C.

bear to the observed induced volts (or counter e.m.f.). Hence, to find the corrected speed it is simply necessary to multiply the observed speed by the ratio

$$\frac{\text{induced volts at } 75^\circ \text{ C.}}{\text{observed induced volts.}}$$

The speed curves for this machine for both directions of rotation are shown in Fig. 40.

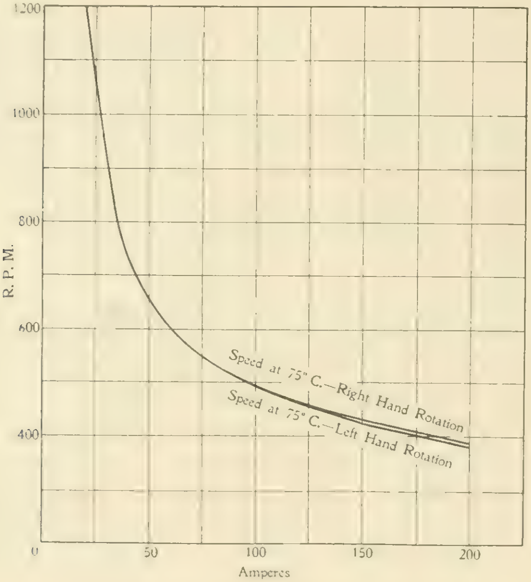


FIG. 40—SPEED CURVES OF SERIES MOTOR

(5) Temperature Tests:

The power losses in electrical machinery of every kind manifest themselves in the form of heat. The elevation of temperature in the various parts of a machine depends on two things: (1) The amount of heat to be dissipated or the amount of the losses in the particular part considered, (2) the ability of the machine to radiate or conduct away the heat developed in it.

There are three ways in which heat is taken from a machine: (a) by radiation, (b) by conduction, (c) by convection or the effect of windage (transfer of heat to the air and subsequent mechanical conduction away from the machine). The first two of these are independent of the speed of the machine, but the last, a very important one, increases greatly with the speed. It is obvious that if a machine is enclosed very little heat is liberated by the first principle and practically none by the last. It will thus be seen that the rating of a machine from the temperature standpoint depends very largely upon the openness of its construction. For consistent results in testing, it is necessary, unless otherwise specified, that all covers should be in place while a temperature test is being conducted. For similar reasons it is important that machines should be screened from draughts.

Generally the object of a temperature test is to ascertain the rise in temperature which will be ultimately reached by a machine running on full load. This may require a run of 6 to 14 hours, according to the size of the machine.

Besides full-load tests, machines are often run at large overloads for short periods, either to determine the over-load capacity of the machine or to prove the fulfillment of special contract conditions.

Preparations for Test—The arrangements for temperature tests are exactly the same as those for regulation, both in the case of generators and motors.

Conduct of Test—Readings of the load are taken at intervals of about one hour in the case of short runs, and two hours in the case of long runs, to determine the progress of the run. Intermediate readings of the load should be taken at intervals, to see that it is held constant. Before the machine is stopped special preparations should be made for the taking of temperatures and hot resistances. At the end of a run the readings to be taken are:

(1) Temperature by thermometer of the various parts of the machine.

(2) Resistances of the various windings while hot so as to be able to calculate the rise in temperature of these parts from the relation of hot and cold resistances.

(3) The temperature of the surrounding air.

The hot resistances are taken exactly as shown in Fig. 3 and described on page 99 in the March issue. A thermometer must be hung in the air near enough to the machine to give a fair indication of the temperature it would have if not in operation, but not near enough to be affected by radiation from it. Immediately after the machine is stopped thermometers should be placed on the various parts whose temperatures are to be measured. Thermometers are required for the following parts of the machine; series field winding, shunt field winding, armature winding, armature iron, and commutator.

They are held in place by means of small pieces of cotton waste wedging their bulbs against the surface. These pieces of waste by reason of their very low conductivity serve to concentrate the heat on the thermometer bulb and also to prevent the radiation of heat from it, when its temperature is above that of the surrounding air. The thermometers are left in place until their readings begin to decrease, usually after 10 to 15 minutes. While the thermometers are being placed in position the resistances of the various circuits must be quickly taken so as to eliminate the effect of cooling as far as possible.

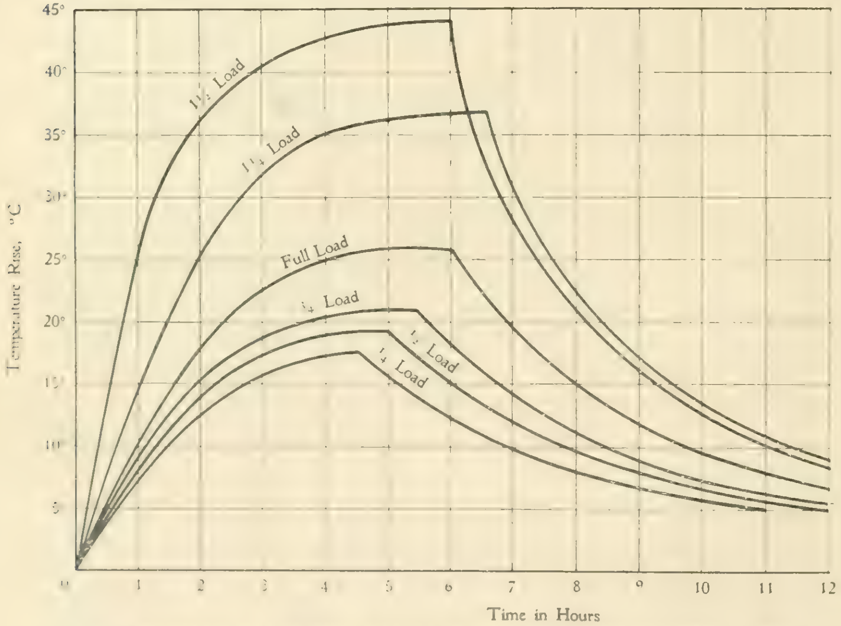


FIG. 41—HEATING AND COOLING CURVES OF A 15 H.P. DIRECT CURRENT MOTOR

The machine begins to cool immediately upon shutting down and a very short delay in taking the resistances will ruin the results of the test. This will be more apparent from reference to Fig. 41. It is customary to take the resistances of both fields before shutting down, leaving only the armature resistance to be effected by a slight cooling.

CALCULATION OF RISE IN TEMPERATURE FROM INCREASE IN RESISTANCE—This method of determining temperature rise is liable to considerable error since its result depends on the accuracy of the small difference between two relatively large measured quantities. The difference between the hot and cold resistances is usually less than 20 percent of the cold resistance, so that any error in the measurement of the resistances may be multiplied five or more times in the resulting temperature rise. The necessity for great care in the resistance measurements is obvious. In addition to this chance for error in the experimental measurements, the correctness of the constants and formulae used in the calculations is at least open to discussion. At the present time the authoritative method is that recommended by the *American Institute of Electrical Engineers* in the Report of the Committee on Standardization, of May, 1902. No one method, however, is in general use. In this article, the A. I. E. E. method will be explained, and its relation to other methods in use will be pointed out.

A. I. E. E. METHOD—This method of calculation is based on the assumption that between any initial and final temperatures copper increases its resistance by 0.42 percent *of its resistance at zero degrees centigrade* for each degree rise in temperature. The equation resulting from this assumption is:

$$A = (238.1 + t) \left(\frac{R_{\text{t plus A}}}{R_t} - 1 \right)$$

R_t=initial resistance at room temperature t degrees C.

$R_{\text{t plus A}}$=final resistance at temperature elevation of A degrees C.

The derivation of this formula is indicated in the foot note of page 8 of the Standardization Committee report.

Corrections—The only correction made in the A. I. E. E. method is for a constant room temperature other than 25 degrees. The report says: "The rise of temperature should be referred to the standard conditions of a room-temperature of 25 degrees C. . . . ." This is done in the following way: "If the room temperature during the test differs from 25 degrees C the observed rise of temperature should be corrected by ½ percent for each degree C. Thus with a room temperature of 35 degrees C the observed rise of temperature has to be decreased by five percent; and with a room temperature of 15 degrees C the observed rise of temperature has to be increased by five percent."

The reason for this correction is not stated in the Standardization report. The effect of a constant room temperature higher or lower than 25 degrees on the temperature elevation of a machine is two-fold:

(a) With a higher room temperature the amount of heat generated in the copper circuits of the machine is greater on account of the higher resistance. On the other hand the loss in the iron is decreased by an increase in temperature. The increase in copper loss, however, undoubtedly overbalances the decrease in iron loss. The numerical value of the change depends on the individual characteristics of the apparatus.

(b) The heat-dissipating power of the air changes with change in temperature. It is not generally agreed whether this change is a decrease in the heat-dissipating power with increase in room temperature, as is assumed by the A. I. E. E. correction, or is in the opposite direction.

In view of these facts the use of the correction for reduction to 25 degrees is of questionable value.

With ordinary room temperatures the correction is small and well within the limits of accuracy of the experimental work and method of calculation.

In commercial testing work in which measured resistances must be checked with calculations and compared with each other it is convenient to reduce all "cold" resistances to the same room temperature, usually 25 degrees. To reduce the cold resistance to 25 degrees, the difference between the air temperature at which the cold resistance is measured and 25 degrees is multiplied by 0.38. This gives the percentage by which the measured resistance must be decreased if the observed air temperature is above 25, or the percentage by which the measured resistance must be increased if the observed air temperature is below 25.

The temperature rise above 25 degrees is then calculated from the formula:

$$a = \frac{R_{t+a} - R}{.0038\ R}$$

a in this case is the rise above 25 degrees. This method of calculation is practically the same as the A. I. E. E. method and is based on exactly the same assumptions, the difference in constant being due to the change in temperature-base.

It is more or less generally assumed that the A. I. E. E. method of calculation is based on correct physical assumptions. This is not true. The assumed constant 0.42 percent is not a constant for different temperature ranges. In view of this, some engineers favor a simpler rule which, while not as correct in form as the Institute rule, can give by proper selection of the constant as accurate results. Such a rule is:

$$A = \frac{R_{\text{t plus A}} - R_{\text{t}}}{.004\ R_{\text{t}}}$$

The resistance readings are used directly without any temperature corrections. This same formula with a constant of .0039 give more accurate results though not so convenient for calculation.

The A. I. E. E. Standardization report makes no provision for a room temperature that varies during the test. If the change in room temperature varies slowly and uniformly as it generally does, it may be assumed with some degree of reason that the temperature of the machine is changed an equal number of degrees, so that the degrees change in air temperature during the test is added to or subtracted from the calculated temperature rise, depending on the direction of the change in air temperature. This assumption is less warranted as the windings are more completely protected from the air by other parts of the machine.

When the room temperature varies during the test the average room temperature should be used in making the A. I. E. E. correction for difference in room temperature from 25 degrees.

It is evident from the preceding discussion that no absolutely right or wrong method of calculating temperature rise can be pointed out.

While it is important that the method used be accurate, it is more important that one method be used universally. At the present time the only method having official standing is that recommended by the *American Institute of Electrical Engineers*, and until a more accurate or more convenient method is regularly adopted the *Institute* method should be used.

SPECIAL TEST:—*Field Form from Measurement of E. M. F. between Commutator Bars*—The principal purposes of this test are: (1) to ascertain the effect of armature reaction in distorting the field; (2) to find the width of the fringe—the spreading of the field—at the tips of the poles; (3) to find the maximum difference of potential between commutator bars.

Preparations for Test—A template must be made from a piece of cardboard shaped as shown in Fig. 42 to be laid around the commutator and of a length sufficient to reach from one brush to the next of the same polarity. Notches are cut in one side of the template to fit around the brushes so that it may easily be held in place. The spaces from brush to brush on the template are divided into parts which are a multiple of the thickness of a commutator bar, plus one mica insulating strip. Making the length of these parts a multiple of the pitch of the commutator bars makes it possible to directly determine the e.m.f. induced in each section of the winding at any particular point of the field, and also a slight error in the division will not materially affect the results. At each of the lines separating these divisions a hole is bored through the cardboard just large enough to receive a very small voltmeter point. The machine is belted up and connected exactly as for a regulation test, being usually run first as a generator separately excited, whether it is designed to run as a generator or as a motor, in order to obtain the curve of field form with no current in the armature.

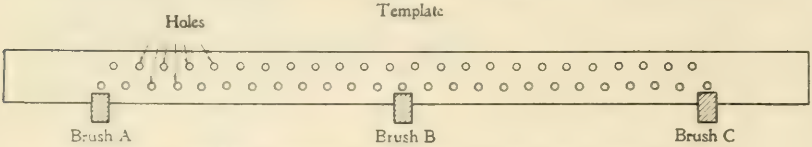


FIG. 42—TEMPLATE FOR TAKING FIELD-FORM CURVES

Conduct of Test—The machine is started up and run at its designed speed. The separate field current is adjusted so as to give the proper terminal voltage. The brushes are set on the no-load neutral and the following readings taken:

(1) Voltmeter readings between adjacent holes in the template.

(2) Speed and field current of the machine.

The last two quantities are to be held constant throughout the test.

When run on load, the machine will in every case be run as in service—as a motor, if it is to be used as a motor, and as a generator if it is to be used as such. It is connected up exactly as for a regulation test, and full-load applied. The brushes and template should be moved around the commutator till the brush position is the same as that at which the machine is to run on load;

the number of commutator bars through which the brushes are moved from no-load neutral position to full-load running position must be carefully noted. The same readings are now taken as those at no-load.

An alternative method, used especially in the case of small motors, is to take both no-load and full-load readings with the brushes in the full-load position and under running conditions. The test is otherwise exactly the same as the one above mentioned.

Precautions to be Observed—If the commutator is at all rough it may be hard to obtain consistent readings due to the intermittent contact of the metal voltmeter points. Better results may often be obtained by using hard drawing pencils as points instead of the customary metal ones.

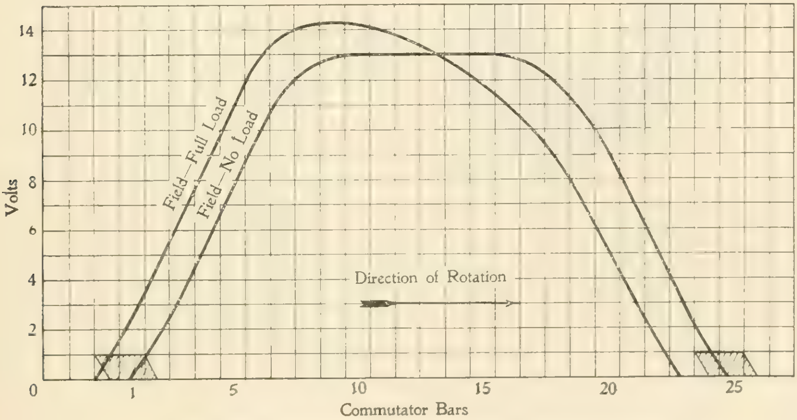


FIG. 43—FIELD FORM OF A 220-VOLT SHUNT MOTOR

Working up Results—Fig. 43 shows the curves of field form taken on a 220-volt shunt-motor. The ordinates are the actual differences of potential read in the test and the abscissae the distances round the commutator starting from one of the brushes. Where the brushes are moved between the no-load and full-load tests the full-load curve must be moved along the scale of abscissae by a distance corresponding to the lead or lag of the brushes as the case may be.

SHOP EXPERIENCE

ITEMS FROM THE NOTE BOOK OF THE APPRENTICE

Indestructible Railway Motor Field Coils.—Street railway motors are probably subjected to more severe service than any other type of electric machine. The conditions imposed by service, size, weight and position of the motor bring about a design, every part of which is entirely different from that of the ordinary motor. This is particularly true of the latest railway motor field coils, in which is employed a construction that reduces the liability of short-circuits and grounds to a minimum and practically eliminates burn-outs due to overheating.

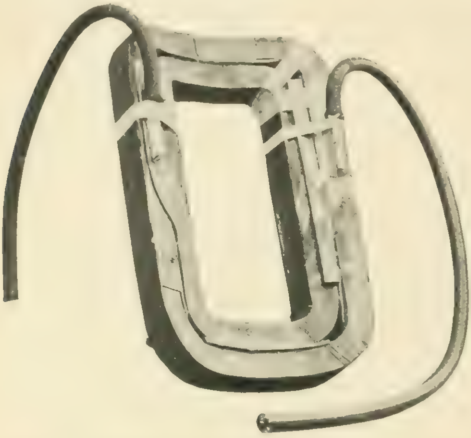


FIG. 1--INSULATED COIL READY FOR THE CASE

In earlier days, field coils were wound with cotton-covered wire which was satisfactory as long as the temperature of the coil remained low. But when the motors were overworked the internal temperature would sometimes rise sufficiently high to char the cotton insulation, and when this happened the jar of the motor would pulverize the insulation and short-circuit the windings. This trouble has been overcome by the use of asbestos insulation which is now used on all railway motor field coils, both wire and strap-wound.

The use of asbestos introduces no new features in the manufacture of wire-wound coils, as the asbestos simply replaces the cotton insulation of the wire. The process of manufacture of asbestos-insulated strap-wound coils is described in the following paragraphs.

Forming the Coil.—The coil is formed from copper strap or ribbon on edge. Before forming, the copper is cleaned by an acid bath and annealed. Four straps enter the machine together, and are formed into coils at the same time; they are clamped between two surface plates to just the proper pressure. Then the entire top bed of the machine rotates through one-quarter of a revolution. The straps are unclamped and the machine is rotated back to its original position; by means of stop blocks the straps are clamped again at the proper point, determined by the dimensions of the coil, and again the bed rotates one-fourth of a revolution to form the second corner. As the turns are formed they are suspended above the machine; when the proper number of turns have been formed the straps are cut, the four coils being together. To separate them, two parallel bars are placed through the coil and one single coil is separated at a time from the others.

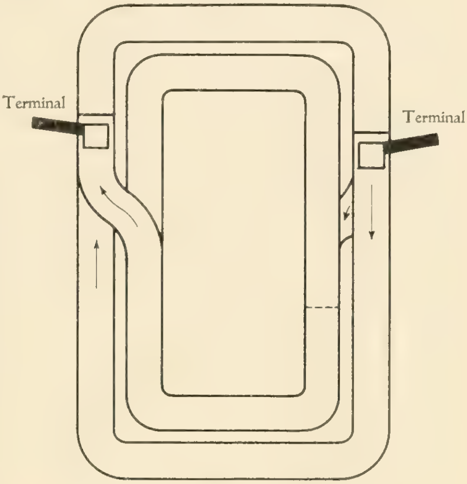


FIG. 2—CONNECTIONS OF COIL

Since the corners of the coil have become hardened on account of the forming operation, the coils must be annealed, which is done by plunging them while red hot in cold water, which also loosens and removes the scale caused by heating; the coil is now ready to be bent into a convex shape between two cast iron formers in a hydraulic press. In the same manner other coils are made of such a size as to fit outside the coils just described, the complete field coil thus being composed of two single coils, as shown in Figs. 1 and 2.

Insulating the Coil.—A layer of asbestos, saturated with shellac, is placed between each turn of the coil; then the insulated coil is clamped in an iron frame and heated until red when all the moisture has been expelled and the shellac dried. Two single coils, one of each size, are now connected in series as in Fig. 2; the coil terminals are riveted and soldered; then to prevent the single coils from touching

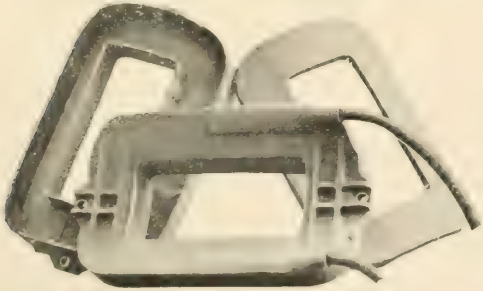


FIG. 3—PARTS OF CASE AND FINISHED COIL

each other, heavy built up mica is driven in between them. This is shown in Fig. 1.

Construction of the Case—In Fig. 3 is shown the case and completed coil. The case consists of the sheet metal sides and lid and a cast metal bottom. The bottom piece carries the terminal tubes and holding lugs. When the coil is on the pole the cast bottom is adjacent to the armature. It is therefore made of high resistance metal to prevent flashing at the brushes.

Every part of the inside of the case is insulated, the corners protected with mica molded to fit, and finally sheet asbestos covering the mica at all points. The insulated coil is placed in the case and built up mica is driven and wedged in between the coil and case; to force the lid of the case down to its proper position it is necessary to use heavy clamps. The necessity of clamps is an assurance against any movement of the coil within the case. After the lid is soldered all around, the clamps are removed. A test of 5,000 volts, alternating, completes the encased coil, shown in Fig. 2. This construction gives a perfectly water-proof and fire-proof coil.

STRUCTURAL STEEL ALTERNATOR FRAMES—The use of structural steel in building up frames for large generators forms a distinctive feature of European design. The advantage of this construction is in the relatively small amount of material required for the frame. The manufacturing conditions, the relative cost of labor and material, and other conditions which prevail in Europe render the saving of raw material a very important item. The different conditions existing in this country, however, makes such a saving of relatively small importance. For this reason structural steel frames have never been employed in American machines.

This frame has been carefully considered in the design of several large American alternators, but it was not adopted. In the case of a 5,000-kw machine it was found that the usual type of cast iron box frame formed approximately 40 percent of the total weight of the machine and probably 10 percent of the total cost. Assuming a structural steel frame to weigh 25 percent of the weight of the cast iron frame, the use of the structural frame represents a saving, considering material only, of 7 percent of the total cost of the machine; but this saving is largely offset by the greater labor expense required by the building and erection of the structural frame. Structural frames require considerably more work on the part of the erecting department, and their success is largely dependent upon the thoroughness of the erection work. This throws a large amount of heavy work upon a department not always well equipped for handling it, making the erection slow and expensive. The erection is especially difficult with machines having frames of the strut construction in which the amount of electrically inactive material is reduced to a minimum. Difficulty has also been experienced in shipping strut frames, it having been found necessary to completely box them, when shipped in sections, in order to give them the necessary support.

Drilling Small Squares or Hexagonal Holes—The usual practice of using a punch or drill and slotter to produce a square hole in a soft metal piece may be obviated, if the desired hole be small, and if the sides need not be perfectly true. The tool employed to drill such a hole is triangular in cross-section and has a round straight shank, clamped in the drill chuck of a high-speed lathe. The free end of the tool carries the cutting edges, which are three in number and ground as shown in Fig. 1. The three edges of the triangular part extending from the shank to the end are not ground and take no part in the formation of the hole, so that the finishing as well as cutting is done by the end face edges. A small hard steel jig is used with this tool. A convenient size is 2"x1½"x¼" and, if a ¼" hole is to be drilled, the hole in the plate should be ¼"x¼"x¼" and located as shown in Fig. 2. A square of the desired size is laid out in the proper position on the piece to be drilled and the steel jig clamped to the piece by means of a small screw clamp in such a way that the outline of the hole in the jig coincides with that laid out on the piece. The lathe is operated the same as in drilling a round hole. The piece is held against the end of the revolving tool by hand, and the edges on the side of the tool striking against the smooth sides of the hole in the jig cause the piece to vibrate rapidly through a small amplitude. The sharp cutting corners which shape the outline of the hole leave a small amount of metal in the corners and middle of each side. A hexagonal hole may be drilled in the same manner by using a templet with a hexagonal hole. The result with either form will not be exact, but approximate enough to fill many requirements. The holes are easily and quickly drilled and may be made as deep as desired within certain limits.

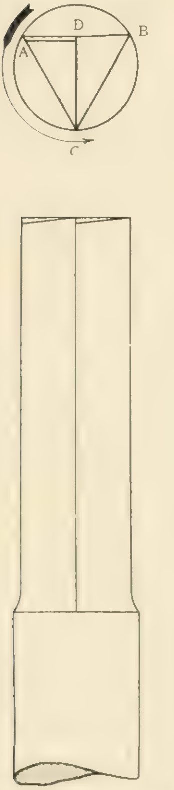


FIG. 1 — SHAPE OF CUTTING TOOL — THE CUTTING EDGES ARE AD, DB AND DC.

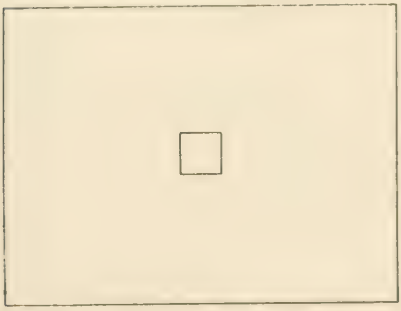


FIG. 2—TEMPLET USED WITH FIG.

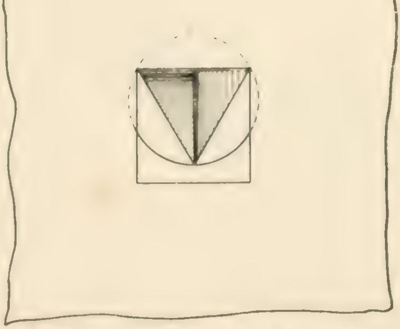
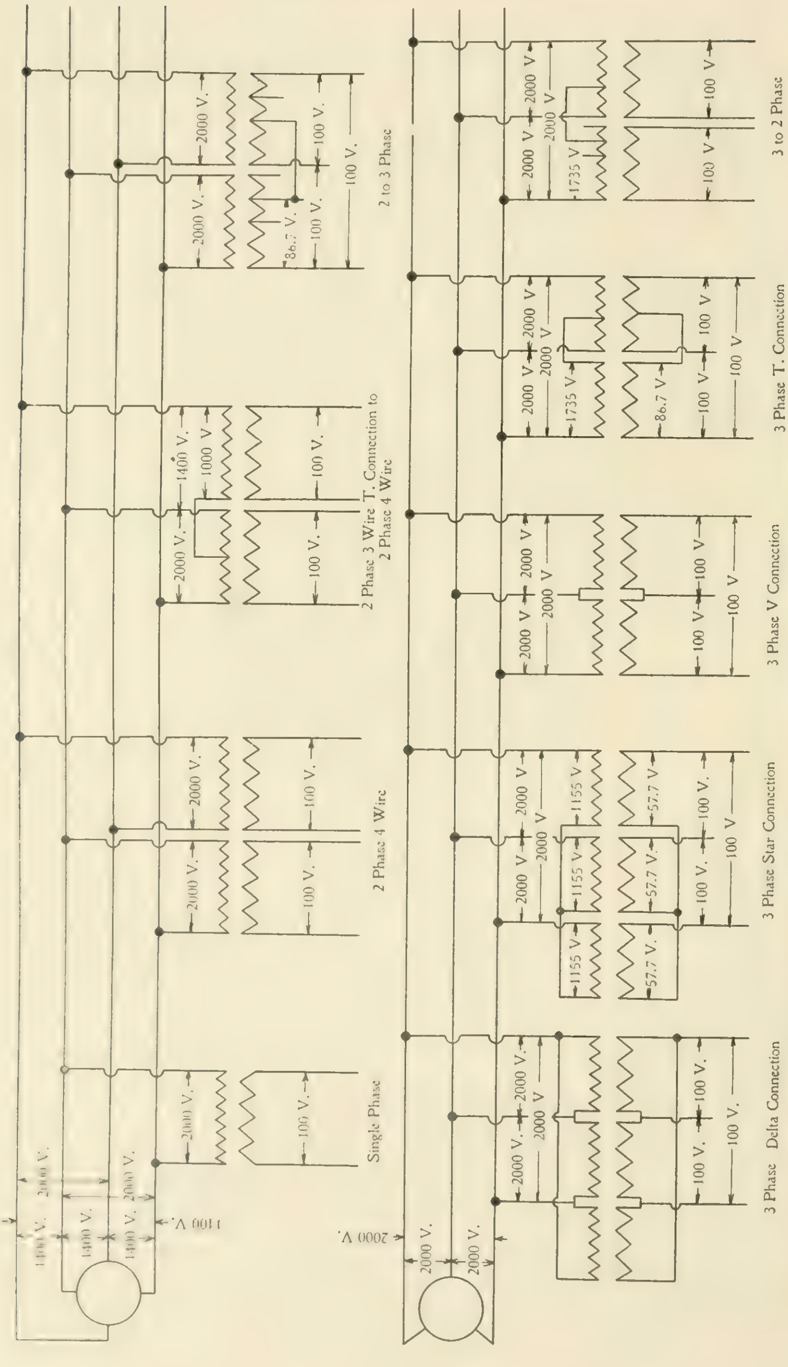


FIG. 3—RELATIVE POSITIONS OF TOOL AND



THE VARIOUS CONNECTIONS OF TRANSFORMERS IN TWO AND THREE-PHASE CIRCUITS

EDITORIAL COMMENT

The Polyphase Induction Motor

It is relatively easy to explain the operation of an electrical machine by a series of mathematical equations, but to translate these equations into English which will adequately set forth the salient principles of the machine is not so easy. The accomplishment of the task, however, has the greatest possible value for that most numerous class of readers who are interested in the operation of the machine rather than in its design.

One of the chief aims of the JOURNAL is the presentation of the principles of electrical machinery upon a physical rather than a mathematical basis, and the article of Mr. B. G. Lamme on the polyphase induction motor in the present issue is one of the best examples of this method of treatment which it has been our good fortune to read. It is noteworthy that this paper, presented seven years ago, stands to-day as an adequate and comprehensive exposition of the characteristics of the polyphase induction motor.

Mr. Lamme's article affords an interesting view of the development of the induction motor. When the paper was prepared in 1897, comparatively few polyphase motors were in use and most of these were started and controlled by variable resistance in the secondary. A very few had cage-wound secondaries, though the great simplicity of such a winding was generally acknowledged to be most desirable. But the cage-wound motor did not at that time come into use because its characteristics were inferior to those of the other type, particularly in the matter of starting. This difficulty was generally thought to be inherent in the type of motor. Mr. Lamme proved conclusively that this was not the case and that such motors, when properly designed, not only have excellent characteristics in general, but can start with a torque so much in excess of that ordinarily required that starting devices may be used which reduce the starting torque. One of Mr. Lamme's objects in presenting this paper originally was to show the remarkable performance and other advantages of the cage-wound motor. The fact that the cage-wound motor has long since become the recognized standard for constant speed work in America and is rapidly attaining the same enviable position in Europe justifies the position which the author maintained.

WITH THE PUBLISHERS

The Up-to-date Engineer

In the early days of commercial electricity engineers were largely recruited from the telegraph engineers, from students whose knowledge of electricity was mathematical, and from that numerous class of electrical tinkers collectively known as bell hangers. As the state of the art advanced, the telegraph engineer learned the difference between operating from batteries and from generators, the theorist learned practice and both of them had to unlearn much of their previous knowledge. In this respect the bell hanger was not in such a bad position as the other two, for while he had more to learn he had nothing to unlearn. The mechanical engineer entered the field later, and with his entrance the electrical art grew most rapidly. In a general way these early engineers may be classified somewhat as follows:—

First, those who were unable to keep up with progress and dropped out, many of them falling into allied lines of business.

Second, those who maintained their place for a certain time (while development was stationary) and then feeling satisfied that they knew all there was to be known, stepped out of line.

Third, the up-to-date engineer who kept in close touch.

This man may have started as a bell hanger with everything to learn, or a telegraph operator, or a pure theorist or more likely a mechanical engineer without any knowledge of the art, but with the ability and will to learn it. And, because this class kept in step with the men who were doing things, it quickly made its influence felt.

When the old direct current lighting plants gained larger and larger circuits, it became evident after awhile to the up-to-date engineer that the direct current system had touched the limit of profitable business. The result was the appearance of the single-phase alternating current lighting system. To the second class of engineers this was something quite new, wholly freakish and uncommercial in its possibilities. To the up-to-date engineer it was a permanent and profitable step forward—to be followed later by the polyphase system with its extensive application to power and lighting service.

As in street railway service it was the up-to-date engineer who made the horse cars and cable cars obsolete, so when further extension of railway traffic became necessary, it was he again who brought forward the polyphase system with its rotary transformers supplying direct current to motors. And now lastly comes the single-phase railway system with its many possibilities.

Though this period of development has hardly rounded out a generation, signs of further evolution are not wanting.

Plainly the question before the up-to-date engineer is not whether he shall try to keep up with the procession, but *how* he shall do it.

At the beginning he is confronted by the largeness of the field to cover, and very likely by his own limited opportunity to gain practical experience. Clearly then the problem resolves itself into one of garnering the other fellow's wisdom. Particularly is this true of the young man, or he who has spent his years in a position of limited opportunity. And yet how seldom is the latter aware that because of the rapidly shifting practice of the day he is likely to round out in quick measure—a miniature of Rip Van Winkle with results quite as disastrous to himself.

And if this is keenly thrust upon his attention, where in the seething maelstrom of electrical activity will he seize the real and true facts, or gather up-to-date information to cope with everyday problems? Is it in the text books? The principles, yes; the practice, no. Indeed, so rapidly does practice change, that much of what is found in text books is obsolete before a second edition is reached; and what is written therein is usually written by men whose view point is theoretic, and therefore often unstable, because the things expounded have not been measured by the rod of experience, and where they have been, as likely as not they have been discarded.

Many an engineer has on his shelves a standard text book on dynamo electricity not over ten years old and the bulk of it is worthless except to archaeological electricians. But the book has a large circulation, and if one were not close to the latest practice he might waste much time in reading it. One may not turn to text books for information on commercial electricity with the same assurance as in the older and more stable professions.

Indeed, the collection of last year's pamphlets, recent magazines and trade circulars is the most useful and valuable part of the practical engineer's reference library. All of which is nearly to the point that what is most recent is best. And this is broadly true, except that regard must be paid to authority. Eliminating the text books then as wholly unsatisfactory, in respect to practice at least, information must be largely gleaned from the electrical papers.

Among these THE ELECTRIC CLUB JOURNAL stands in the very front rank, whether you judge it by its circulation or the quality of its articles. First, and distinctly, it is not a news sheet, but a high grade engineering magazine of which one of the most prominent consulting engineers said, "Per square inch of superficial area, it is capable of doing much more practical work than the average electrical journal." Which remark leads us to emphasize one of its strongest points—its intense practicality. So far as possible the theoretical treatment of subjects is avoided. So far as possible results are presented graphically by an abundance of curves and diagrams utilized in the explanation of the principles and methods of electrical science. And that its reading pages shall not approximate to some kind of electrical pemmican diet, of which the reader will soon tire, occasional articles of general interest are introduced.

As is quite well known THE ELECTRIC CLUB JOURNAL is published by The Electric Club, an organization of the engineers and apprentices of one of the largest electrical works in the world. In the JOURNAL are printed the club lectures and discussions—the honey of a mighty beehive of electrical endeavor.

The scope of the JOURNAL is not, however, limited to the transactions and proceedings of the club. It prints papers read before societies or conventions which are appropriate in character, but may not be readily available to the members of the club. It contains also helpful editorials, real engineering data, items of improved shop practice and bits of real experience not otherwise accessible.

The rapid progress of electrical practice will quickly place any man who ceases to keep posted out of date in from three to five years. There are no signs that development has reached a stationary level. For example, five years ago there were very few street railway operators who had to deal with alternating current, whereas at the present time there are a multitude of roads using alternating current and rotary converters for transforming to direct current. It is likely in five years more that the whole equipment will be alternating current. The purpose of the JOURNAL is to keep its readers posted regarding these changes of practice.

In referring to the evolutionary tendency in the American iron and steel industry, an English engineer recently said: "The most remarkable industrial development in the history of iron making is mainly the result of two factors, the popularization of practical science by the American scientific journals and the courage and inventive genius of the American iron masters."

These remarks apply with equal force to the electrical field. Its journals have been the large factors in keeping men up-to-date and the courage and inventive genius of the master electricians have not been surpassed since the beginning of the world in any line of human activity.

PERSONAL MENTION

Joseph Adams, of The Electric Company, died at his home in Knoxville, Pa., Friday evening, the 12th of August. Death was due to pneumonia, which he had contracted on the preceding Monday. He leaves a wife and one small child.

Joseph Adams was born in 1876, and after his education was completed came to The Electric Company in 1894 as a correspondent in the Direct Current Department, in which position he remained two years, then leaving to accept a position with the F. F. Nicola Company, dealers in lumber. In 1896 he returned to his former position, which he retained until the organization of the Price Department in February, of this year, when he was promoted to a responsible position in the new department.

His industry and close application to business had won him the respect of all, and his genial and obliging manner endeared him to those with whom he came in frequent contact. The early death of Mr. Adams cuts short, at the age of 28, a most promising career.

Mr. J. H. Hallberg of New York has been retained as consulting engineer for the Atlantic Mills, Providence, R. I. Extensive electrical developments are under way at these mills which will probably require an ultimate electrical equipment of 4,000 horse power.

Mr. P. W. Ripple, formerly of the Detail Engineering Department, has accepted the position of Electrical Engineer with the Lehigh Valley Railroad, under Mr. A. E. Mitchell, Superintendent of Motive Power. Mr. Ripple's headquarters will be at South Bethlehem, Pa.

CLUB NEWS

Report of the Excursion Committee—During the past year The Electric Club has conducted excursions to industrial establishments in the neighborhood of Pittsburg, according to a new plan that has worked very successfully. In previous years one excursion was arranged each month, which was attended by all members of the club so inclined. This plan resulted in a small number of large and unwieldy excursions. In the new plan, which has been in operation during the past year, excursions were arranged by the individual members of the club and the Excursion Committee obtained passes requested by members. Passes were not obtained for parties of less than 10 nor more than 15 men, except in a few special cases. The small number in each party insured adequate attention from the guide for each man in the party. During the eight months from October 1, 1903, to June 1, 1904, about 45 excursions were made to 30 different plants. One man in each party was required to write a report of the excursion, and these reports have been typewritten and filed in the office of the Secretary, where they are accessible to members planning similar excursions.

Library Gift—The Electric Club Library has recently been increased by a large number of books presented by the D. Van Nostrand Company of New York. The collection includes many standard works of reference by well-known electrical and engineering writers and published by this company. The usefulness of the library will be greatly increased by the addition of this gift.

That the inquiries from women visitors to the Westinghouse exhibit at the St. Louis Fair are not looked forward to by the patient apprentice who is on duty to instruct the ignorant, is evidenced by the following conversation:

"Pardon me, sir, does your company make electric heating irons?"

"I am sorry, madam, but we don't make those articles."

"Well, I declare! And I thought the Westinghouse Company was such a wonderful company." And the lady turned her back in disgust.

A lady of more intelligent mein wandered up to the aforesaid patient youth. "Those are Cooper Hewett lights and those Bremer lamps," he said in answer to her inquiries.

"Of course the Westinghouse only makes the best kind of electricity?"

"There is only one kind, madam," said he of the patience.

"You mean to tell me that that white light and that yellow light are the same?"

"One is carbon and one, mercury incandescence, but both caused by the same kind of electricity."

"I don't understand, and I don't believe you do," she declared. "I suppose if a hen laid two eggs and one was bad and one was good you would consider them of the same quality just because the same hen laid them." Crushed with this unanswerable logic, the Socrates of electrical philosphy hurried to the recuperating assistance of the nearest electric fan.

An Apprentice.

OF INTEREST TO COLLEGE MEN

During the past three months the following men have entered the apprentice course:

For the sake of convenience in reading, the list is classified by institutions.

ARMOUR INSTITUTE OF TECHNOLOGY.
Arthur Buie.
G. W. Borst.
Morris J. Knapp.

BALTIMORE POLYTECHNIC INSTITUTE.
George F. W. Sims.

BLISS ELECTRICAL SCHOOL.
S. S. Darrall.

BROOKLYN POLYTECHNIC INSTITUTE.
C. P. St. John.

CASE SCHOOL OF APPLIED SCIENCE.
L. F. Grant.
E. R. Spencer.
H. A. Kuehle.
P. E Lohman.

COLUMBIA UNIVERSITY.
W. A. Daly.
I. Jarcho

GOLOGNE UNIVERSITY, GERMANY.
H. Hermann.

CORNELL UNIVERSITY.
A. M. Buck.
A. N. Brutley.
S. B. Charters.
E W. Clarke.
R. A. Smith, Jr.
Wm. Southwell.
Roland S. Trott.
George W. Walker.
C. L. Wernicke.

ONE OF THREE STEAM TURBINES BEING INSTALLED FOR THE PENNSYLVANIA, NEW YORK & LONG ISLAND RAILROAD.

This photograph was taken at the time of the initial test, on which occasion numerous engineers of prominence were present.

The machines are of 7500 h.p. normal capacity, with 175 pounds boiler pressure and 28″ vacuum, running at 750 revolutions per minute. By means of the secondary governor valve these turbines will automatically carry double load under normal operating conditions, as well as about 20% overload when exhausting into the atmosphere. The dimensions of the turbine including the generator are as follows: Maximum length, 47 ft. 3¼ in.; extreme width, including platforms, 15 ft. 8 in.; maximum height above floor level, 14 ft. Total weight, including generator bed-plate but not generator, 350,000 lbs. Weight of revolving element of turbine, 47,600 lbs. Approximate weight of revolving field of generator, 90,000 lbs.

THE
ELECTRIC CLUB JOURNAL

VOL. I OCTOBER, 1904 NO. 9

ELECTRIC RAILWAY BRAKING

By E. H. DEWSON
Chief Engineer of the Westinghouse Traction Brake Co.

WITH the introduction in electric railway practice of methods and equipments more and more nearly approaching steam railway standards, the use of power brakes has become wider and more general. Their adaptation to the electric railway car has made possible the stage of progress reached to-day in the electric railway field, where large, heavy cars are being operated at speeds which in many instances are as high as those found in the operation of trains on our steam railways.

As was the case in steam railway history, numerous friction and clutch brakes were experimented with in the early development of the electric railway car. At the present time, however, these types of brakes are hardly ever installed, having been superseded by power brakes of either the air operated or electrically operated type. In the first air brakes used on electric railways, the compressor supplying the air was so arranged as to be driven from the axle by means of gearing. This type of machine was known as the axle-driven compressor. It is to-day largely superseded by a compressor driven by a separate electric motor, and of this type is the great majority of modern air brake equipments. This change came about from two causes. In the first place, the axle driven compressor requires considerably more care and attention to insure its proper maintenance than does the motor-driven machine. In the second place, the high speeds at which electric cars came to be operated made it advisable to adopt some other method for supplying the air than through a machine driven from the axle.

The primary cause of the introduction of power brakes was, of course, the comparative degree of safety in operation of cars. But since the general introduction of power brakes in electric railway service, attention has been drawn to the economies effected by their use, and their influence in increasing the earnings of the road.

When the cars of an electric railway are equipped with power brakes, it is possible to operate safely at a much higher speed, and, consequently, to maintain more frequent service without the first cost and the maintenance expense of the additional cars which the slower schedule speed would necessitate. Another feature of the air brake that is of importance to the electric railway manager is the economy in power consumption which comes as a direct result of the installation of air brakes. Tests made by well-known electric railways in both city and suburban service have shown that, of two cars, one equipped with air brakes and the other not so equipped, the hand brake car consumed from ten to fifteen percent more power than the air-braked car. This striking difference is due to the practice—so common and necessary with motormen who have only a hand brake on which to depend—of keeping the brake shoes close to the wheels so that they may be able to make a quick stop when it is necessary and be confident of complete control of their car at all times.

The air brakes in use on electric railways to-day may be classified in two ways: source of power and manner of its application. Under the first classification the two most popular types of air brakes are the motor compressor type and the storage type. In the former the source of the power is the small motor-driven compressor mounted on the car; in the latter the immediate source of the power is the tanks on the car, which are filled with an air compressor at stations along the line of the road. With reference to the manner in which the air is used to operate the brake, we have three representative forms of air brakes: straight, automatic, and a combination of these two. In the series of articles of which this forms the first we shall discuss the motor compressor type of brake, first taking up both the straight and automatic forms of this equipment and following these articles by a discussion of the storage air brake.

For cars which operate singly or haul not more than one trailer, the straight air brake is generally used, and as these represent the service conditions present on most of the electric roads of to-day, the straight air brake is the type most commonly seen. In this form of apparatus the air from the compressor is stored in a reservoir, from which it is piped to an operating valve, and then to the brake cylinder. In operating the brakes the operating valve is moved so as to admit air from the reservoir to the brake cylinder, and in releasing the same, the port from the main reservoir is closed and the air from the brake cylinder allowed to exhaust into the atmosphere.

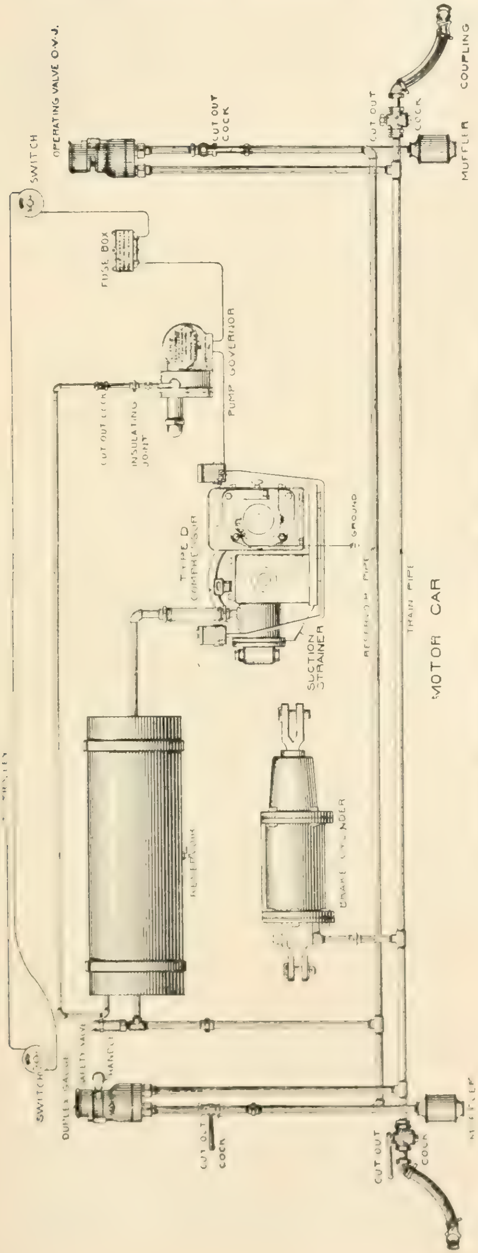


DIAGRAM SHOWING A STRAIGHT AIR BRAKE EQUIPMENT

A straight air brake equipment of this type should include the following:

A motor-driven air compressor which is usually suspended beneath the car.

An automatic electric pump governor to maintain a pressure in the main reservoir as nearly constant as practicable, by stopping the compressor at a predetermined maximum pressure and starting it when the pressure in the main reservoir falls below a predetermined minimum. This governor should be provided with an insulating joint and a cut-out cock, the latter to cut it out of the system in the emergency of anything going wrong with its mechanism.

A fuse to protect the motor compressor circuit.

A snap switch for each cab, placing control of the electrical circuit in the hands of the motorman no matter at which end of the car he may be.

A safety valve to prevent

the possibility of over charging the main reservoir or the piping system.

An operating valve for each cab by means of which the motorman can apply or release the brake.

A duplex gauge for each cab to indicate to the motorman the pressure in the main reservoir and also that in the brake cylinder.

A brake cylinder provided with a hollow rod and loose push rod and crosshead which makes it possible to apply the hand brake without moving the piston, thus avoiding unnecessary wear and useless expenditure of force.

A main reservoir for the storage of compressed air.

At the present time there are a number of air brake systems on the market but only two that are well known and widely used: The Christensen Air Brake, manufactured by the National Electric Company, Milwaukee, Wis., and The Westinghouse Air Brake manufactured by The Westinghouse Air Brake Company at Wilmerding, Pa., for the Westinghouse Traction Brake Company of New York City. Each one of these companies offers various combinations of equipment with different sizes of brake cylinders, main reservoirs and compressors and different types of operating valves to suit the varying local conditions.

In order to design an air brake for a car of any type it is necessary to know the light weight of the car including trucks and motors, but without live load. On this point depends the size of brake cylinder to be used in order to secure, through a scientifically designed system of leverage, the requisite pressure on the brake shoes. This matter will be discussed in detail in a later article, but it may be well to say here that the force applied to the wheels of free axles is figured at ninety percent of the pressure of these wheels on the rails, while that applied to the wheels of motor equipped axles is figured at one hundred. This difference is due to the necessity for overcoming, on the motor equipped axles, the rotary energy of the armature as well as the momentum of the car. After having determined the size of the brake cylinder to be used, the next point to be settled is the size of the compressor that should be included in the equipment. This depends on the weight of car or cars to be braked and upon the frequency of braking. Another important point in deciding on the size of compressor, and one that is frequently overlooked, is the number of air-operated auxiliaries to be supplied from this source.

Whistles to be operated by air taken from the air brake supply are frequently installed on electric cars and the necessity for frequent use of these whistles, often of a large size, will, in the case of a car weighing 50,000 pounds or over, in many instances, require an amount of air equal to that used in braking. In addition to furnishing air for the whistles the air-brake compressor is frequently called on to supply air for pneumatic sanders, trolley retrievers, gate openers, and other devices which are more or less extravagant in their use of air, all of which must be considered in determining the size of the motor compressor.

The main reservoir should have a capacity sufficient to supply the air necessary for three or four applications of the brakes without a reduction of more than twelve or fifteen pounds in the reservoir pressure. It is of no small importance to have a reservoir as large as possible on the car since this will result in considerable saving in the cost of maintenance of the motor compressor. If the reservoir is too small every ordinary application of the brake will bring the compressor into action, causing unnecessary wear on both compressor and pump governor. With straight air-brake equipments the pump governor is ordinarily set to stop the compressor when a pressure of sixty-five pounds is reached in the reservoir and to start it when this pressure has dropped to fifty pounds. Consequently the volume of the main reservoir should be such that the withdrawal of four complete cylinders full of air will not reduce the reservoir pressure more than twelve to fifteen pounds. The Westinghouse Traction Brake Company has established a number of standard sizes suited to the conditions offered by cars operated singly and equipped with straight air brakes. These standards varying from a reservoir 16″ in diameter and 48″ long for an 8″ brake cylinder to 16″ in diameter and 84″ long for a 14″ brake cylinder represent what is regarded as standard practice of to-day.

The number of cab equipments furnished depends, of course, on whether the car is to be operated from one end only, or from either end, and constitutes another point to be borne in mind in designing straight air brakes.

The advantage of the straight air brake lies in its directness and simplicity and in the fact that it requires less skill to make an exact stop with the straight air brake than with an automatic air brake. Its greatest disadvantage is due to the fact that in the event of a break in the piping or in the hose connections between the cars, if operating in train, the motorman is left with nothing but the hand brake on which to depend. Another disadvantage which is apparent when operating in trains is that the brakes of the different cars do not act simultaneously, due to the frictional resistance of the train pipe, thereby causing a disagreeable and even dangerous bumping and jerking of the cars.

(TO BE CONTINUED IN NOVEMBER)

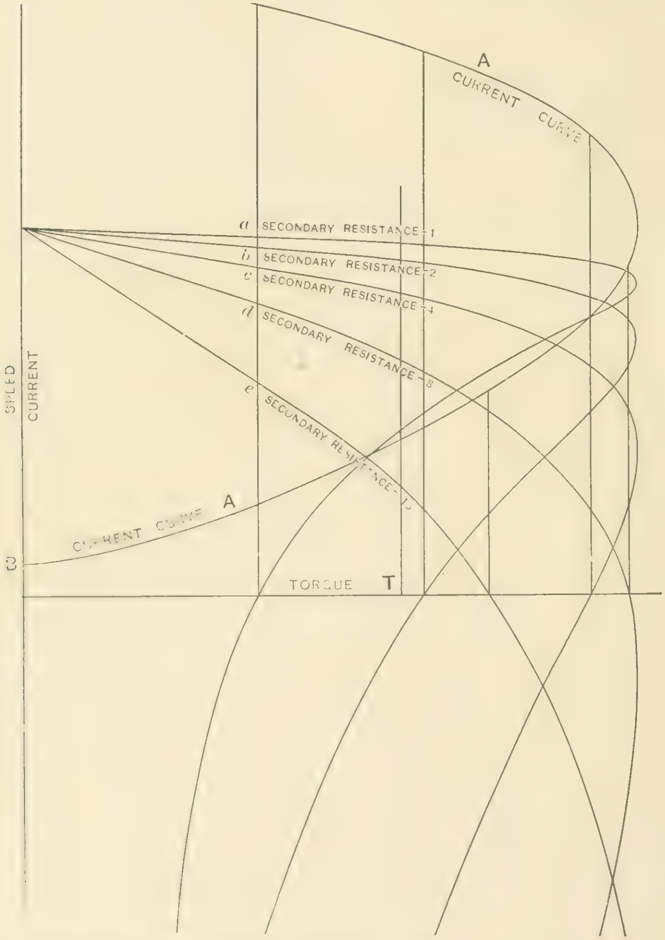


FIG. 6—SPEED-TORQUE AND CURRENT-TORQUE CURVES OF POLYPHASE MOTOR WITH SECONDARIES OF DIFFERENT RESISTANCES

THE POLYPHASE INDUCTION MOTOR

PART II

By B. G. LAMME

[Numerous references are made in this installment to Fig. 6, which appeared on page 442 of the September Journal. For the convenience of our readers we have reprinted Fig. 6 on the opposite page.—Ed.]

MOTORS FOR VARIABLE SPEED WORK

FOR variable speed work, such as cranes, elevators, etc., the series of curves in Fig. 6 show one method of regulating the speed. By varying the secondary resistance over a wide range, any speed from zero to maximum may be obtained with any torque up to the maximum. This requires the use of collector rings and adjustable rheostats. The variations in speed are obtained by wasting energy in resistance. For a given torque the same power is expended on the motor whether the speed is zero or maximum. To obtain a certain torque at start requires as much power as when running at full speed.

An analysis of the motor shows another way in which the speed-torque curves may be varied. In Fig. 6 all the curves show a certain maximum torque which is the same in all cases; but this is with the condition of constant primary electro-motive force. By varying the electro-motive force applied to the primary we may obtain a quite different series of curves. Taking, for example, a speed-torque curve of the form *a* in Fig. 11, and applying a higher electro-motive force to the primary, a curve is obtained of the same shape as *a* but with a much higher point of maximum torque. Lowering the applied electro-motive force, the maximum torque is lowered. The torques at any given speed are raised or lowered in the same proportion as the maxima are varied. At any given speed the torques are proportional to the square of the electromotive forces applied. This relation holds good for any form of the torque curve, whether of the shape *a, d* or *c* shown in Fig. 6.

The current curves are also shown in Fig. 11. They all have the same general shape, but have different maximum values, these being proportional to the electromotive forces applied. The speed-torque curve *a* in Fig. 11 has the same shape as *d* in Fig. 6, which gave too great a drop in speed. In Fig. 11, curve *b*, which is the same form as *a*, gives less speed drop for the same torque. Curve *c* gives less than *b*, and has fairly good speed regulation from no-load up to normal torque *T*. But this result is obtained at the expense of increased induction in the iron, and large no-load or magnetizing current, due to the higher electromotive force, is required. If it is possible to obtain a speed torque curve like *c* in Fig. 11, with the normal electromotive force applied, we can obtain good speed regulation from no-load up to the rated torque, and shall be able to start the motor with the maximum torque it can develop. Then by lowering the applied electromotive force, the same form of speed torque curve will be retained, but the starting torque and starting current may be lowered to any extent desired.

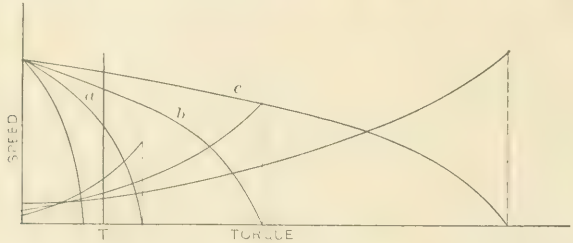


FIG. 11—SPEED-TORQUE AND CURRENT-TORQUE CURVES OF POLYPHASE MOTOR WITH DIFFERENT VOLTAGES APPLIED

Variable Speed by Varying Voltage—Returning to Fig. 5*, it was stated that the peculiar shape of this curve, with the torque falling rapidly after reaching a maximum value, was due mainly to magnetic leakage between the primary and secondary windings. But if the motor is so proportioned that the leakage is very small compared with the useful field, the speed-torque curve takes a quite different shape. The maximum torque is increased directly as the magnetic leakage is diminished. This is shown in Fig. 12. Here *a* is similar in shape to curve *a* in Fig. 6; *b* represents the speed-torque curve with the magnetic leakage reduced one-half; *c* represents it with about one-half the leakage of *b*, and *d* with one-half that of *c*.

In comparing Figs. 6 and 12, it may be noted that *a* in one is the same form as *a* in the other, although drawn to a different scale.

---

*See page 441, September Journal.

In Fig. 12, *b* has the same shape as in Fig. 6, but has a different maximum value. The same is true of curves *c* and *d* in the two figures. By lowering the applied electromotive forces for curves *d, c* and *b* of Fig. 12, so that the maximum torques are equal to that of *a,* as shown by the dotted curves, we get practically the same curves as in Fig. 6.

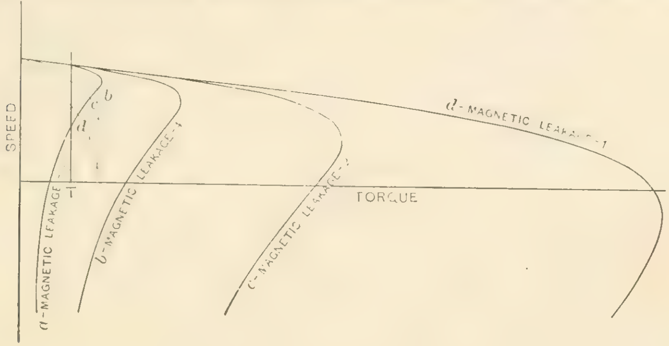


FIG. 12—SPEED-TORQUE CURVES OF POLYPHASE MOTOR, SHOWING EFFECT OF MAGNETIC LEAKAGE. DOTTED LINES SHOW b, c, d WITH REDUCED VOLTAGE

Curve *d,* in Fig. 12, gives as good running conditions as curve *a* in Fig. 6, having about the same drop in speed at the normal torque T. We have then in *d,* a curve which starts at the point of maximum torque, and which also has a small drop in speed at the normal load. The objection to this curve is that the starting current and starting torque, although in the proper proportion to each other, are both much greater than is necessary or desirable. By reducing the applied electromotive force at start, however, lower torques and currents are obtainable. In this way we may combine good starting and good running conditions in one motor without the use of starting resistances, and with a secondary that has no

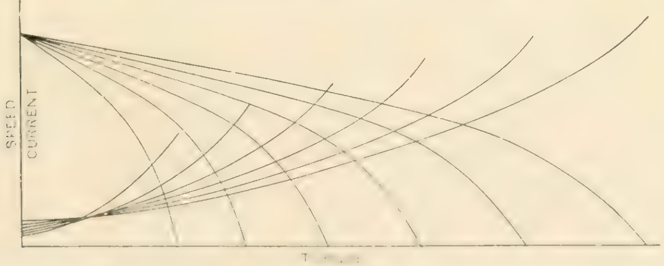


FIG. 13—SPEED-TORQUE AND CURRENT-TORQUE CURVES OF POLYPHASE MOTOR WITH ELECTRO-MOTIVE FORCE VARIED OVER A WIDE RANGE

resistance except that of its own windings. Fig. 13 shows the speed-torque and current curves of such a motor, with the applied electromotive force varied over a considerable range.

If but one electromotive force is desired for starting and speeding up, and the motor is then to be transferred to the working electromotive force, the speed-torque curves should preferably have the shape shown in Fig. 14. The motor starts with the desired torque at reduced e.m.f. and comes up to almost rated speed before switching over. This is suitable for constant speed work. In Fig. 14 are shown both the starting and running speed-torque curves, and the currents both in the motor and the line. The line currents are smaller than the motor currents in the ratio of reduction of electromotive force in the regulating transformers.

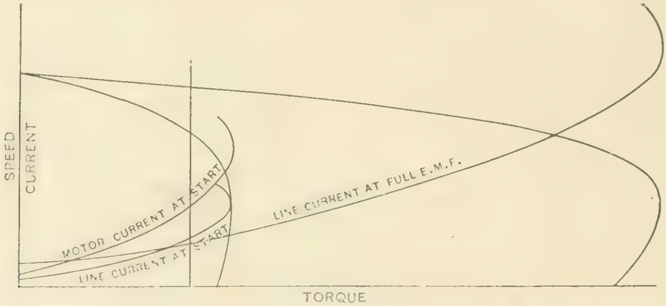


FIG. 14—BEST SHAPE OF SPEED-TORQUE CURVE OF MOTOR STARTED AND SPEEDED UP WITH A SINGLE REDUCED VOLTAGE, BEFORE BEING TRANSFERRED TO THE WORKING VOLTAGE

Speed-Torque Curves for Variable Speed Work—For cranes, elevators, and variable speed work in general, curves of the form shown in Fig. 15 are preferable. The line currents are also shown in this figure. This series of speed-torque curves shows that a wide range of speed may be obtained by proper variations of the applied electromotive force. The line currents *A*, *B*, etc., practically overlap each other. This means that the line current required with this method of control, is nearly constant for any given torque, independent of the speed. The same is true of the method of control by varying the secondary resistance. It may be noted that the current for starting, as on curve *C*, for instance, is slightly greater than that required for running at the same torque on *B* or *A*. This is due to the speed-torque curve being somewhat curved at its outer end. With a somewhat higher resistance of the secondary, the curves are more nearly straight, but the drop in speed is somewhat increased on the speed-torque curve for any given electromotive force. In practice a compromise is made between the best possible starting condition and a condition of less speed drop.

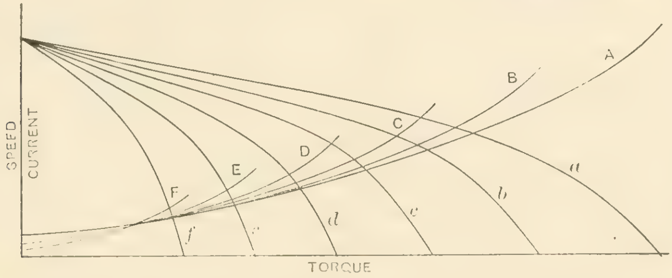


FIG. 15—SPEED-TORQUE AND CURRENT TORQUE CURVES OF MOTOR FOR CRANES, ELEVATORS AND SIMILAR VARIABLE SPEED WORK WITH VOLTAGE CONTROL. CURVES a, b, c, d, e, f ARE SPEED-TORQUE CURVES WITH VARIABLE VOLTAGE CURVES, A, B, C, D, E, F SHOW THE CORRESPONDING LINE CURRENTS

A comparison of the methods of control, by varying the secondary resistance and by varying the applied electromotive force, shows that they give practically the same results in regard to starting, speed regulation, etc. But a motor that has been designed for regulation by varying its secondary resistance, will generally give very poor results when an attempt is made to operate it by the variable electromotive force method. A motor must be especially proportioned for small magnetic leakage when this method of control is to be used. The proportions and the arrangement of the parts are such as may class this as a practically distinct type of motor.

Efficiency and Power Factor—We come now to the other characteristics of the polyphase motor, the most important of which are the efficiency and the power-factor. The importance of efficiency is generally appreciated, but the question of power-factor in most cases appears to be not thoroughly understood, or else is entirely overlooked.

The efficiency of a polyphase motor is the ratio of the power developed to the true power expended, as in any other kind of a machine. The power developed may be obtained from the speed-torque curves. If the torque is given for one foot radius, and the speed in revolutions per minute, then the product of any given torque by the corresponding speed, divided by 5,250 will give the power developed in horse power; or torque multiplied by speed, divided by seven, gives the power developed in watts. This power, plus the iron, copper and friction losses, gives the true power expended.

The power-factor is the ratio of the true power to the apparent power expended. This apparent power is proportional to the products of the primary currents by the electromotive forces. If there is magnetizing current, and if the motor has magnetic leakage, the primary currents are not in phase with their electromotive forces, and their products represent an apparent power which is greater than the true energy expended. The current of each circuit can be considered as made up of two currents, one of which is in phase with the applied electromotive force, representing true energy, and the other at right angles to the electromotive force, representing no energy. This right-angled component is the one that has an injurious effect on the regulation of the generator, transmission lines, transformers, etc.

The size of this component, compared with the useful current, may be shown by a table:

Power Factor.	Total Current.	Useful Component.	90 Degree Component
100	100	100	0.
99	100	99	14.2
98	100	98	19.9
95	100	95	31.2
90	100	90	43.6
80	100	80	60.0
70	100	70	71.4
60	100	60	80.0
50	100	50	86.6
40	100	40	91.6

Effects of Lagging Current—At ninety percent power-factor, for instance, the current that is lagging ninety degrees behind the electromotive force is equal to 43.6 percent of the total current flowing. This lagging current reacts on the generator, affecting the regulation. In an alternating-current generator, a ninety-degree lagging current in the armature coils directly opposes the field magnetization. When delivering a current at ninety percent power-factor, there is over forty-three percent of this current opposing the field, and at eighty percent power factor, sixty percent is opposing the field. If the armature ampere turns are normally twenty percent as great as the field ampere-turns, then a load of eighty percent power-factor will give an opposing magnetization in the armature of about sixty percent of the total armature ampere-turns, or about twelve percent of the total field, and the armature electromotive force will be lowered approximately that percent more than with a load of one hundred percent power factor.

The inductive effects of the lagging current in the transmission circuits and transformers are much more serious than those from a current that is in phase with the electromotive force. The generator, transformers, lines and motors also have increased losses, due to the large current required when the power-factor is low. An eighty percent power-factor in a system means losses, due to heating of conductors, more than fifty percent greater than those with one hundred percent power-factor. These figures indicate the importance of good power-factors in an alternating current system.

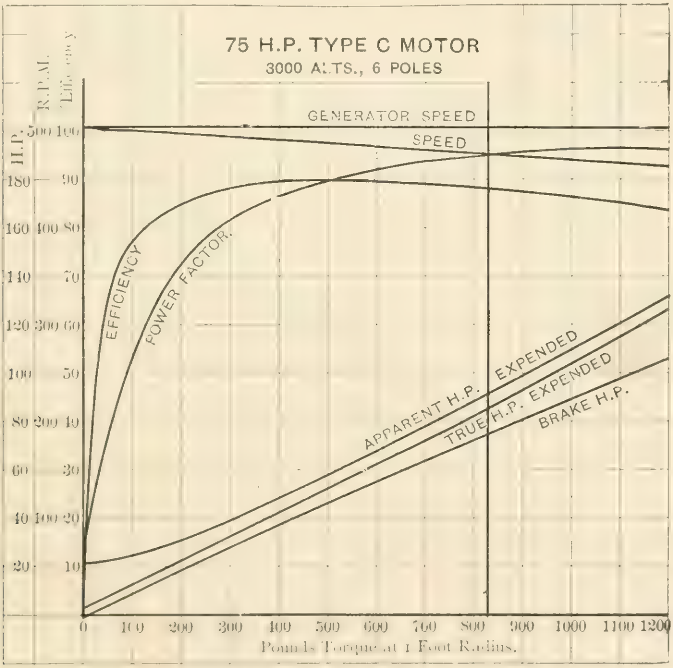


FIG. 16 PERFORMANCE CURVES OF A 75 HP TYPE C MOTOR

Magnetizing Current and Magnetic Leakage determine Power-Factor.—The lagging or ninety-degree component of the current in a motor depends upon the amount of the no-load or magnetizing current, and upon the magnetic leakage. Let this lagging component be expressed in percent of the total current. Also express the magnetizing current in percent of the total current, and the total magnetic leakage in percent of the total primary induction. Then the sum of the percents of magnetizing current and magnetic leakage represents very closely the percent of the lagging component of the primary current. If, for example, the magnetizing current is 30 percent and the leakage is 14 percent, the resulting lagging component is about 44 percent. From the preceding table, this indicates about 90 percent power-factor. A low leakage and a high magnetizing current may give the same power-factor at full load as a high leakage and low magnetizing current; but at half load, the percent magnetizing current is practically doubled, while the percent magnetic leakage is halved. Hence, a low magnetizing current is of great importance in maintaining a high power-factor. If a high value of power-factor over a wide range is desired, then both the leakage and magnetizing current must be low.

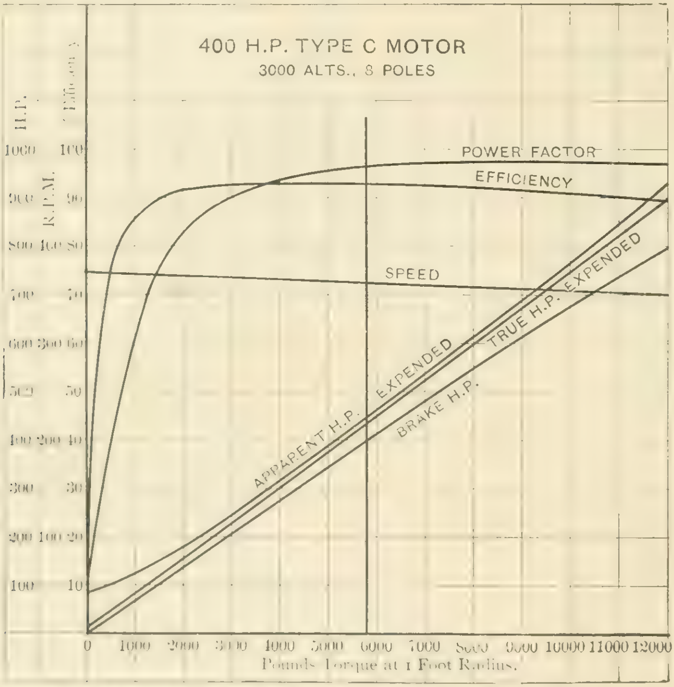


FIG. 17—PERFORMANCE CURVES OF A 400-HP TYPE C MOTOR

Voltage Control versus Rheostatic Control—The method of control by varying the primary electromotive force is dependent upon the fact that the motor has a low magnetic leakage. By using certain proportions and arrangements of the windings on the primary and secondary, the magnetizing current may be made comparatively low. Thus both conditions for good power-factor are obtained.

With the method of control by varying the secondary resistance, good power-factors may be obtained. But the form of secondary winding required when variable resistances are used, tends to reduce both the power-factor and the maximum torque.

Best Form of Secondary Winding—An elaborate series of tests was made, to determine the best type of winding for the secondary of a polyphase motor. First, two circuits were arranged to give secondary phases ninety degrees apart. The starting, running and maximum load conditions were determined. Then a three-phase secondary winding was used. This gave a higher pulling-out torque and better power-factor than the two-phase. Four phases were tried, and were better than three; and six were better than four. Then twelve phases were tried, with a gain over six in the maximum torque, but not much gain in efficiency. The power-factor was somewhat improved. Finally the winding was completely short-circuited on itself, all coils being connected to a common ring. This gave a further increase in maximum torque and power-factor over the preceding arrangement, but there was very little gain in efficiency. The same primary was used in all these tests. Each time the number of secondary circuits was increased, the power-factor was somewhat improved. This was due to the fact that the secondary currents were able to so distribute themselves that the local electromotive forces in the coils, due to leakage, were diminished; or, the magnetic leakage may be considered to have been diminished. This would necessarily give higher pulling-out torques and higher power-factors.

Best Form of Primary Windings—Very complete tests were also made to determine the best form of primary winding, and a certain method of distribution of the coils was found to diminish the primary magnetic leakage very considerably. This somewhat increased the maximum torque and the power-factor. Utilizing the arrangements of the primary and the secondary windings just described, and otherwise proportioning for small magnetic leakage, a motor may be obtained that has a comparatively low total induction, and yet has a magnetic leakage of but a few percent. The low induction allows a small magnetizing current and comparatively low iron losses. The low leakage gives a high pulling-out torque, and thus allows a good speed regulation, and also good starting conditions, by varying the applied electromotive force.

MOTORS FOR CONSTANT SPEED WORK.

Motors that are adapted for operation under the conditions of variable applied electromotive forces, with constant secondary resistance, must have the special forms of speed-torque curves shown in Figs. 12 and 15, and they may therefore be considered as forming a distinct type. In Westinghouse manufacture this type has received the name Type C. The Type C motor is always characterized by low magnetic leakage and consequent high pulling-out torque. The secondary has no adjustable resistance, and all regulation is obtained by varying the adjustable electromotive force. The secondary is made the rotating part, on account of the type of winding used, which consists of copper bars placed in tunnels or slots in the core, and bolted to two end rings. There are no bands, and the question of insulation is of very little importance, for the maximum secondary electromotive force does not exceed three volts in a 500 horse-power motor, and is less with smaller sizes.

Advantages of Type C Motors—This type of motor possesses several distinct advantages over other forms of polyphase motors. The method of control, by varying the electromotive forces applied to the motor, leads to two very important advantages, one of which is mechanical and the other electrical. With this method of control there are no regulating appliances on the motor and, in consequence, it may be of the simplest possible form. The electrical advantage is that the motor may be started and controlled from a distance. Thus it may be placed entirely out of the reach of the operator. On traveling cranes, for example, this is of special advantage, for in this case only the primary wires need be run from the operator's cage to the motor. If there are several motors on the crane, there may be one wire common to all the motors, and but two additional wires per motor are required. Thus, for three motors, a minimum of seven trolleys wires may be used.

If the variable electromotive forces are obtained from transformers, the switches for operating several motors may be wired to one set of transformers, and the motors may be started and regulated independently. For traveling cranes only one set of transformers is used for the hoisting, bridge and traveling motors, and this set may supply currents at different electromotive forces to all the motors at the same time. A further advantage possessed by this motor lies in the high pulling-out torque. If a heavy overload, or a load having great inertia, is suddenly thrown on a motor that has a speed-torque curve like *a* in Fig. 6, the point of maximum torque may be passed for an instant, and the motor will be stopped unless the load is quickly removed. A Type C motor in this case would have its speed pulled down for a moment, but this reduction in speed gives an increased torque, thus enabling the motor to carry the overload.

If the electromotive force of the system is suddenly lowered, the pulling-out torque of the motors is lowered very materially. A reduction of twenty percent in the electromotive force will lower the pulling-out torque to about two-thirds of its former value. Even with a temporary drop in the electromotive force, such as would be caused by a momentary short circuit on the lines, this may be sufficient to stop the motor. But a motor that has a pulling out point several times as large as its normal running torque is very rarely in danger of being shut down from this cause. This type of motor has a starting torque from two to four times as large as the full load running torque, and it is thus able to start any kind of load. In practice the starting torque is adjusted to the load to be started, by applying a suitable electromotive force, as will be explained below.

A last, but not least, advantage of the Type C motor is its adaptability for large sizes. The larger the motor of this type, the lower in proportion can be its magnetic leakage and its magnetizing current. In consequence, the power factors are very high. The efficiencies are also very good over a wide range of load. The curves for a seventy-five-horse-power, six-pole, 3,000 alternation motor are given in Fig. 16; also, the curves for a 400-horse-power, 2,300 volt, eight-pole, 3,000 alternation motor in Fig. 17. The power-factors of these motors are good examples of what can be obtained on large motors of this type.

[Owing to the length of Mr. Lamme's article it will be impossible to conclude it in this issue of the Journal as originally intended. The article will be concluded in the November issue.]

THE SINGLE-PHASE RAILWAY MOTOR

By C. R. DOOLEY

A REVIEW OF THE MORE IMPORTANT FEATURES OF THE ALTERNATING CURRENT RAILWAY MOTOR

ALTHOUGH much has been written of the single-phase railway, its principles of operation and the economies to be effected by its use, many persons connected with electrical industries are still inclined to regard it as something vague and mysterious, something entirely new and different from the present direct-current railway motor.

It is a matter of everyday experience that if the current in both field and armature of a direct-current series motor is reversed, the direction of rotation of the armature will be unchanged. If the current supplied to such a motor were reversed once an hour or once a minute, we would not expect to find any essential difference in the operation of the motor, and with more frequent reversals of the current the same principles in general should apply. With a direct current rapidly reversed, an effect similar to that produced by an alternating current is obtained and therefore it is only natural to expect that alternating current applied to a direct-current series motor should produce continuous rotation of its armature. It is upon this fact that the operation of the single-phase railway motor depends.

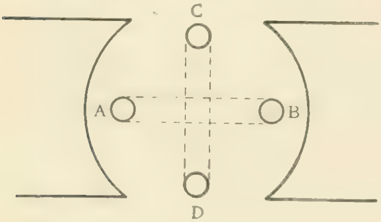
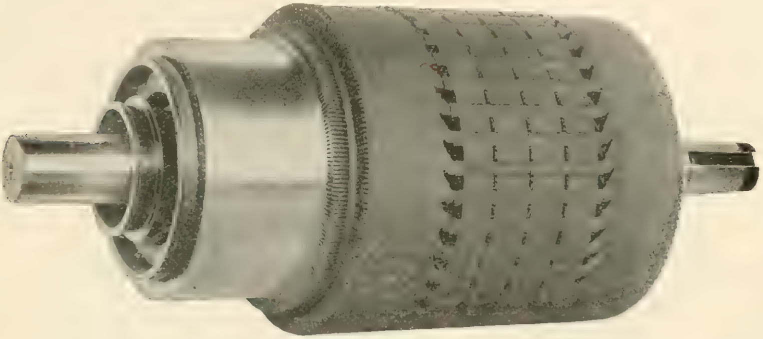


Fig. 1

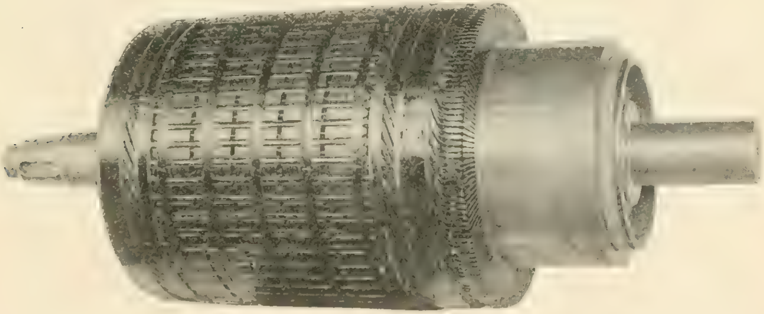
While in general a series motor will operate with alternating-current as well as with direct-current, yet there are certain phenomena peculiar to alternating-currents that make the practical operation of the motor a more difficult problem than one might imagine from the above.

One of these phenomena is the loss which occurs in any solid iron core if the magnetism is rapidly changed in strength or reversed in direction. This loss can be greatly reduced if the iron core is made laminated instead of solid. With alternating current flowing in the coils of a motor, the magnetism induced will of course vary in strength and direction as the current varies. Hence in order that the series motor may operate satisfactorily with alternating current, the magnetic circuit must be laminated.



ARMATURE OF A 150 HP SINGLE-PHASE ALTERNATING-CURRENT RAILWAY MOTOR

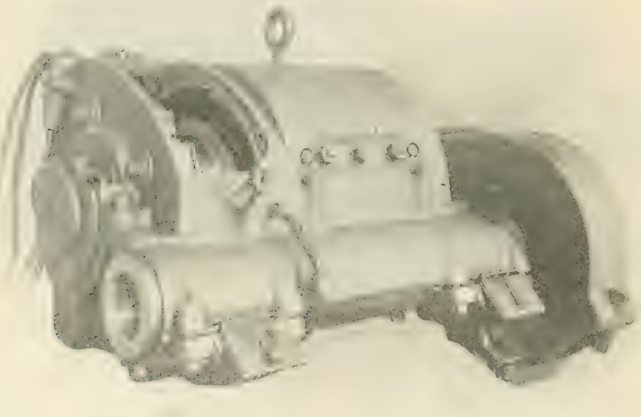
A more serious difficulty due to the alternating magnetism is the transformer action which occurs between armature and field. Let C D (Fig. 1) be an armature coil in a two-pole machine, at position of commutation. Owing to the passage of alternating magnetic flux from one pole to the other, there will be a voltage induced in each of the various armature coils by transformer action, entirely independent of their speed of rotation. This voltage will be different in the different coils, depending on their position, and will be a maximum in the coil C D which is at right angles to the flux and zero in the position A B.



ARMATURE OF A 150 HP DIRECT CURRENT RAILWAY MOTOR

As each commutator bar passes under a brush an armature coil is momentarily short-circuited.

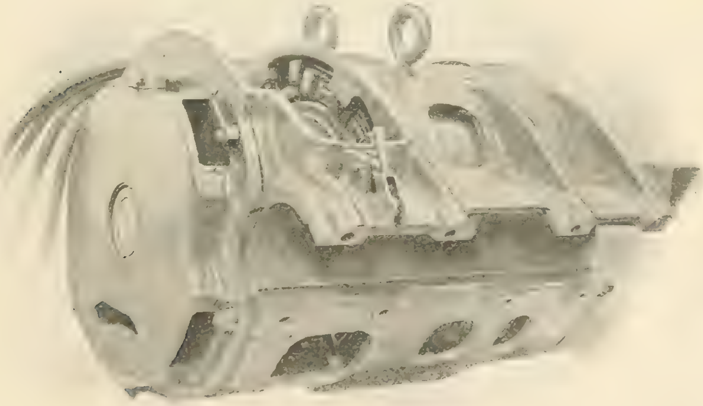
The armature coils are thus short-circuited consecutively in the positions where the greatest e.m.f., due to the transformer action, is induced in them. The result is an excessive current in each coil at the moment it is commutated, in much the same manner as results in an ordinary transformer having a short-circuited coil, and this current may be several times as great as the working current and would be disastrous to commutation and also would be a source of excessive armature heating from the short-circuited coils if means were not taken to prevent or reduce it. Other things being constant, the value of this induced e.m.f will be proportional to the frequency of the alternating current supplied and therefore the alternating current motor is most easily designed for low frequencies. The first designs by Mr. Lamme were built for 2,000 alternations, but later developments, such as the auxiliary field winding arranged between the poles in such a manner as to have a neutralizing effect upon the self-induction of the armature, have made good performance possible on 3,000 alternations, which is happily the standard frequency used in the majority of present installations of power transmission.



FRONT VIEW OF 150 HP DIRECT CURRENT RAILWAY MOTOR

In general appearance the alternating-current railway motor closely resembles the direct-current railway motor; in fact, the resemblance in many details, as well as in operating characteristics, is most surprising. The frame of the alternating-current railway motor, like that of the direct-current motor, is of cast steel, but the entire magnetic part of the field (poles and yoke) is laminated. This differs from the direct-current motor, where the poles alone are laminated and the cast steel frame also acts as the magnetic yoke. Like the direct-current railway motors, the alternating-current motors in general have four poles, although a greater number is used in the larger sizes. The poles of the alternating-current motor are shorter than those of the direct-current motor and carry only a few turns of heavy strap winding.

The armature is in all essentials similar to that of the direct-current motor, having much the same general dimensions and fitted with the same commutator. Instead of only two brush arms, however, the lower voltage and consequently larger current motors of the alternating type require one set of carbon brushes per pole, in order to avoid excessive commutating current. The armature and field coils are connected in series precisely the same as in the direct-current motor, but there is an auxiliary field in addition which is also placed in series with the main field and armature. The speed and torque curves of an alternating current motor are shown in Fig. 2 and a similar set of curves taken on a direct-current motor of the same size is shown in Fig. 3. These curves will readily be seen to


FRONT VIEW OF 150 HP SINGLE PHASE ALTERNATING CURRENT MOTOR

be of the same general character. It may be noted in this consideration of general performance that while both the alternating and direct-current motors require some controlling device whereby the motor is started under a reduced voltage, yet, should energy conditions require it, the alternating-current motor may be started on full voltage with small danger. The direct-current motor must always be started on a reduced voltage.

For small equipments a controller similar to that used in direct-current equipments is recommended. Here the controller drum cuts in and out successive taps on the transformer in a similar manner as the series resistance is cut in and out in the case of direct-current motors. Thus all losses from series starting rheostats are entirely eliminated.

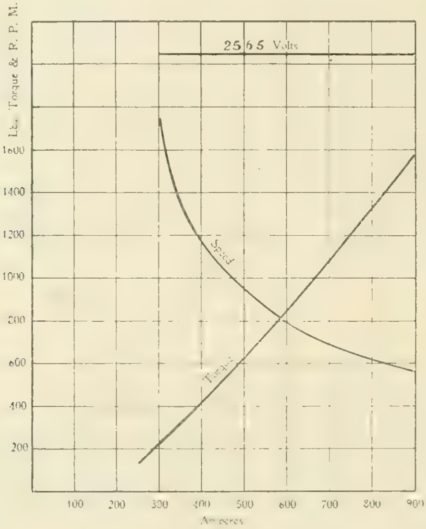


FIG. 2—SPEED AND TORQUE CURVES OF AN ALTERNATING-CURRENT RAILWAY MOTOR

For large equipments the controller takes the form of an induction regulator and is in short a boosting transformer placed in series with the motor. This transformer or regulator boosts up or down, depending upon the relative position of the regulator primary, which is movable and is operated from the motorman's cab.

The alternating-current motor is reversed in precisely the same manner as the direct-current motor; that is, by reversing the relative series connection between the armature and field coils.

The ratings given to the alternating-current motors correspond closely to the ratings given to similar sizes of direct-current motors. The rated load may be defined as such a load which the motor will carry at rated voltage for one hour with a rise in temperature in the windings of approximately 75°, temperatures measured by thermometer. In general the motor will carry continuously from 45 to 50 percent of its full-load current at the reduced average voltage in service.

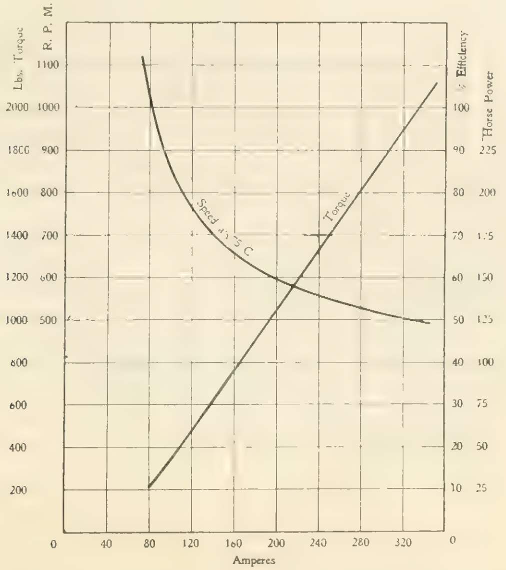
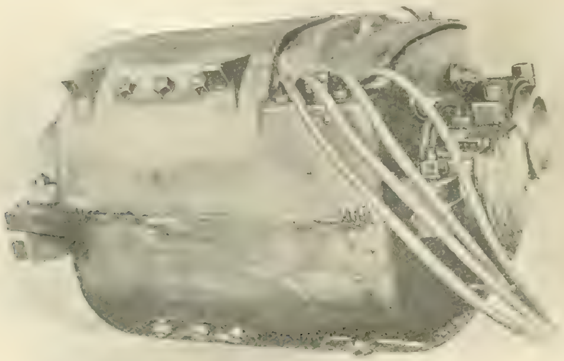


FIG. 3—SPEED AND TORQUE CURVES OF A DIRECT-CURRENT RAILWAY MOTOR

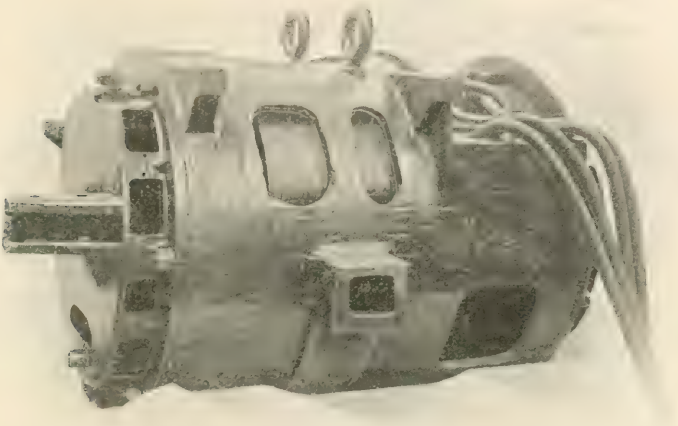
In considering the power-factor of the alternating-current railway motor, it must not be confused with the power-factor of an induction motor. In the case of an induction motor there is a large inductive element and in order to produce a good torque, not only a heavy current must be drawn from the line, but also considerable real energy. In the alternating-current motor the torque depends on the current only, and a large torque at low speed requires but little real energy. Therefore the power-factor of an alternating-current railway motor is low, not because there is a large inductive component, but because there is a small energy component.

The operation of a direct-current railway system has been eminently satisfactory for two reasons: First, the direct-current series motor, owing to its variable field has speed-torque characteristics particularly suitable for railway work. Second, only a single trolley is required. With the establishment of long trolley lines came the problem of transmission which was solved by the use of alternators at the generating station and rotary converters at sub-stations along the line. The rotary converter has been well termed the weakest link in the chain. It is costly to install and expensive to operate partly on account of loss of power but more especially on account of the constant and skillful attendance necessary. It is the element most likely to interfere with continuous operation.



REAR VIEW OF 150 HP DIRECT-CURRENT RAILWAY MOTOR

It has been the endeavor then, in the development of the alternating current motor, to perfect a motor that may be operated directly from the alternating-current transmission line, and at the same time give the satisfactory performance that the direct-current motor is giving. Such a motor as is now being installed on a number of roads by the Electric Company, represents the latest development and offers several advantages. The most notable saving is through the elimination of all intervening rotating machinery, thus lessening the attendance necessary at the sub-station, as well as avoiding one of the greatest sources of trouble. A high trolley voltage is employed effecting a saving in the line construction. No power is lost in starting or running at reduced speeds, the motor can therefore be run continuously on any intermediate speeds. In addition it will be remembered that the alternating-current motor possesses the same speed-torque characteristics as the direct-current motor and is operated from a single trolley.



REAR VIEW OF 150 HP SINGLE-PHASE ALTERNATING CURRENT RAILWAY MOTOR

It is notable that the single phase apparatus does not involve radical changes such as would be experienced if the new system used polyphase currents and induction motors, but that it retains the essential elements of the direct-current system.

SHOP TESTING OF GAS ENGINES

By E. E. ARNOLD

SHOP testing of gas engines, and in fact of any form of prime mover, may be divided into two classes, viz:—(a) Special or research testing of new designs for special service, in which many refinements may be entered into; and (b) Regular commercial testing of the standard product, the success of which depends largely upon its economic performance.

The latter class should be conducted by every manufacturer of machinery on account of its particular interest to the commercial engineer and the prospective buyer from the standpoint of insuring more perfect operation and an authoritative record of economy before the engine leaves the builder's hands. Testing of this nature should, of course, be conducted so as to approximate as nearly as possible every-day working conditions, and the results should be determined with commercial accuracy, but without undue complication of the apparatus involved.

VIEW OF GAS ENGINE TESTING FLOOR

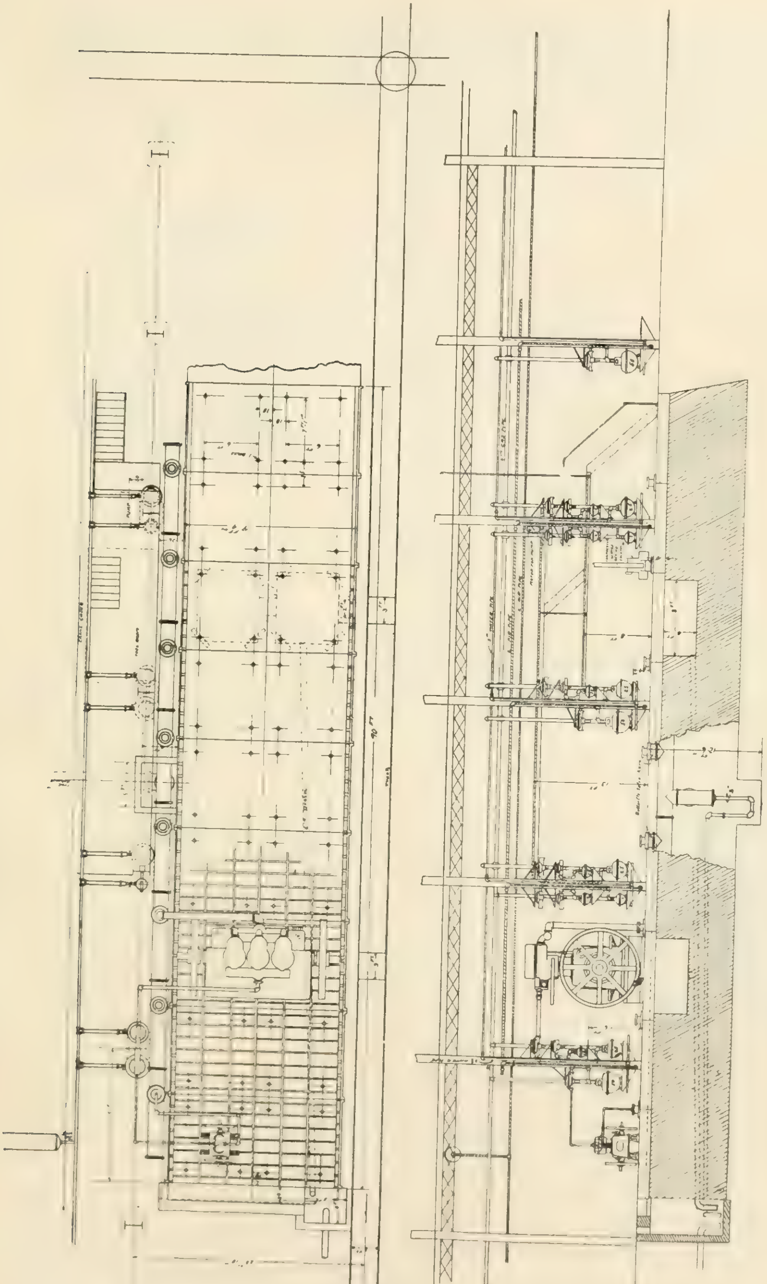
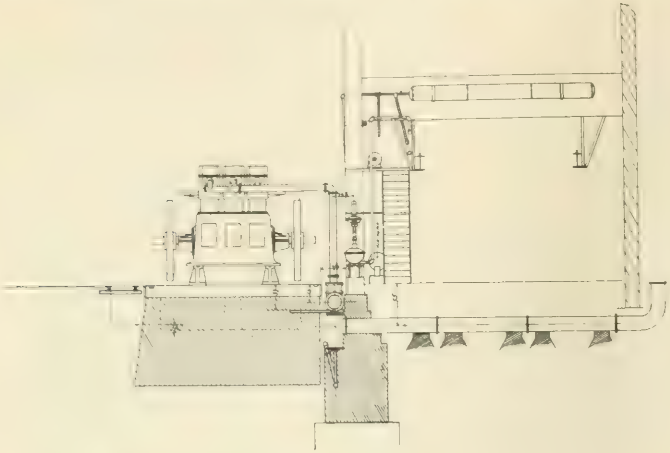


FIG. 1—PLAN AND ELEVATION OF GAS ENGINE TESTING FLOOR

This can best be accomplished by employing only the simplest methods and apparatus, which of themselves will greatly eliminate instrumental and personal error and at the same time render the records comprehensive by the exclusion of all extreme refinements.



SECTIONAL ELEVATION OF GAS ENGINE TESTING FLOOR

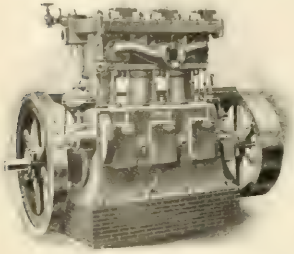
Equipment.—The first consideration for a shop testing system should be a suitable foundation upon which various sizes of engines may be easily and substantially erected. Sources of gas, water, and air supply, electric igniting circuits, and exhaust connections should be easily accessible.

Such a testing floor is shown in plan and elevation in Fig. 1, and consists of simple longitudinal and transverse T-slotted surface plates laid upon a solid concrete block. Two fly-wheel pits are provided in the concrete, which may be utilized by lifting the section of surface plate immediately above them. The T-slots of the surface plates serve the double purpose of taking the heads of holding-down bolts, and of acting as a drainage system by connecting with the gutters extending along either side.

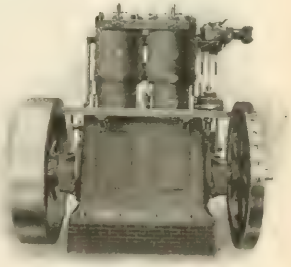
Gas meters and gas regulators of various sizes are arranged in tiers upon brackets on either side of a row of columns. These columns also support the water and air pipes, which terminate with snap couplings near the floor.

Several sources of ignition current are available, such as storage batteries, low voltage magnetos, and small independent 100-volt generators; and as an emergency source, the switchboards are connected to the direct-current shop power circuits.

The exhaust line is laid in a pit between the line of columns and the surface plates and is provided with openings, each of which may be closed by a butterfly valve to prevent the escape of exhaust gases into the shop or to allow them to pass through other engines which may be connected up but not running. The portable apparatus used in conjunction with the floor and its fittings is duplicated in various capacities. Prony brakes and indicator riggings are provided for each size of engine manufactured so as to be easily applied with a minimum waste of time in adjustments. The instruments used are: indicators, calorimeters, speed recorders and tachometers.

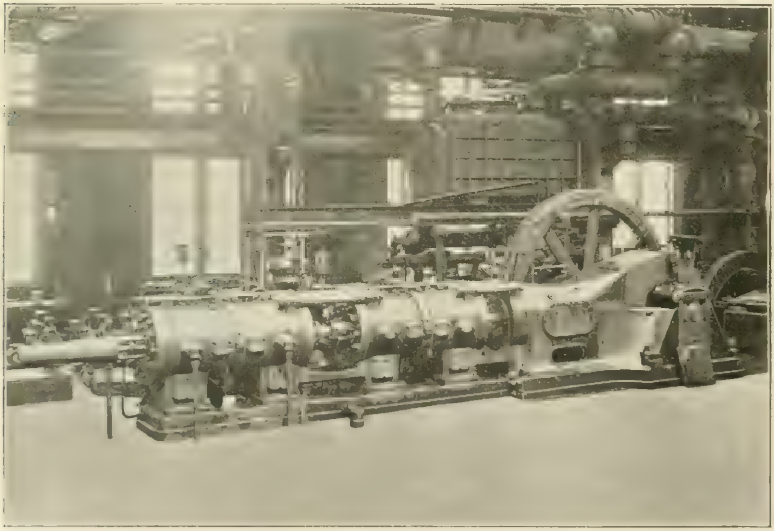

THREE-CYLINDER GAS ENGINE

Conduct of Test.—A clear understanding of the methods of commercial testing may be best obtained by following through a test on some particular engine. Take, for instance, a 175 horse-power, three-cylinder, vertical-type engine. Run to be made on natural gas. The engine is new and after it is set up on the testing floor with its valves set in standard position, it must be run a short time without load and then with load for another brief period in order to wear off its initial stiffness. As soon as the bearings are in good running condition permanent adjustments are made for continuous running.


TWO-CYLINDER GAS ENGINE

A preliminary run is now made in which the load is applied to the ultimate capacity of the engine; speeds are taken at various loads and the governor is set to give the required regulation. Gas readings are taken for the purpose of adjusting the mixture. In the test run it is customary to take the rated load first, then the over-load (which should be about 15 per cent above the rated capacity of the engine) then the half-load, and finally the no-load. This routine is followed for two reasons: First. After the test is once started the gas adjustments must remain unchanged. It is obvious, therefore, that the adjustments should be made when the engine is developing its rated capacity. Second. The normal speed of the engine is adjusted for its full-load operation and a regulation curve determined within certain limits above and below this point.

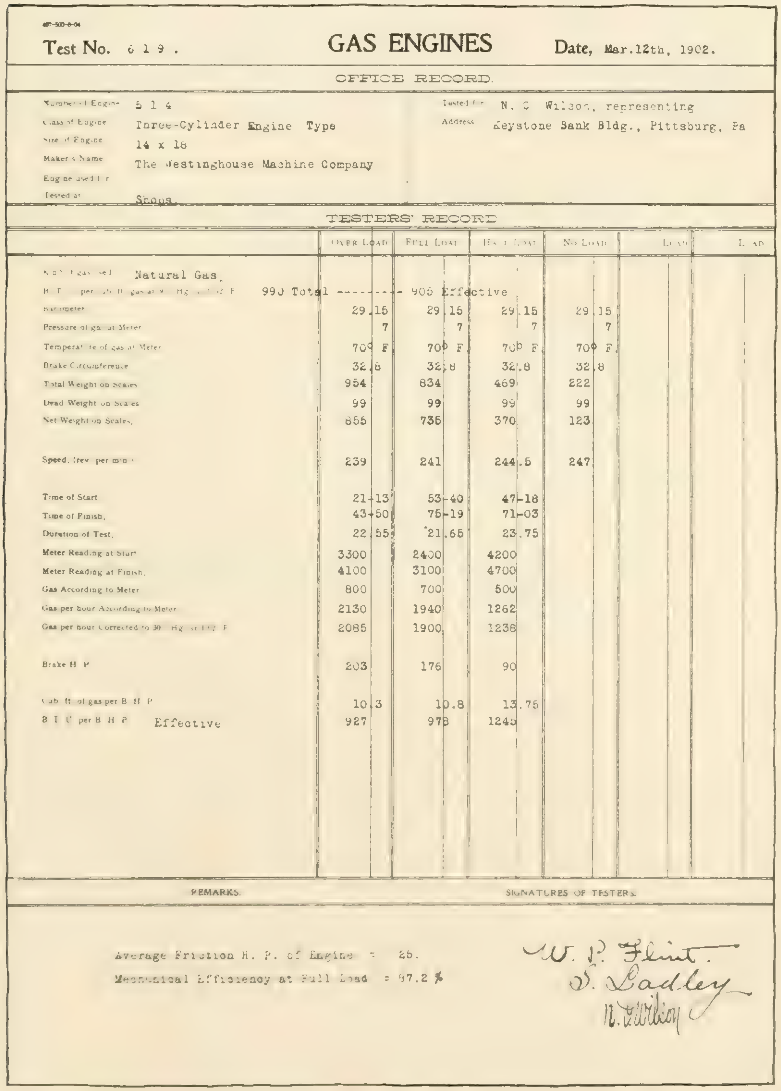
Without entering into a detailed description of the readings taken during one of these runs, a sample log sheet is here given which shows a complete test upon the type of engine above referred to. It will be seen from this that the essential points to be determined are, in order of significance: (a) the measurement of the loads upon the engine by means of the prony brake, (b) the speed in revolutions per minute, (c) the accurate observation of the time of start and finish of the test taken to the nearest second, (d) the reading of the gas meter and consequent determination of the cubic feet power hour at the different loads. Corrections must be made for pressure and temperature, which are observed by manometer and thermometer at the gas meter. The performance of the engine is finally expressed in terms of British Thermal Units contained in a cubic foot of gas, and for this determination a tap is run off the main gas line and a Junker calorimeter used from time to time. The values thus recorded serve for all the tests being run at approximately similar times, as it has been observed that the gas varies but slightly from day to day.



LARGE HORIZONTAL GAS ENGINE

Indicator cards are taken from each cylinder during the various runs and copies of these for the typical runs are posted in the record books with the log sheets. Occasionally indicated horse-power is calculated from these cards, but as a general rule, unless special tests are being run, the cards are used only to check up valve settings, and to more or less indicate whether proper combustion is taking place in the cylinders.

Results of a Test—The log sheet and curves for a very complete test on a 175 horse-power engine are given below, and these show in



407-500-8-04

Test No. 6 1 9. **GAS ENGINES** **Date,** Mar.12th, 1902.

OFFICE RECORD.

Number of Engine 5 1 4
Class of Engine Three-Cylinder Engine Type
Size of Engine 14 x 18
Maker's Name The Westinghouse Machine Company
Engine used for
Tested at Shops.
Tested for N. C. Wilson, representing
Address Keystone Bank Bldg., Pittsburg, Pa

TESTERS' RECORD

	Over Load	Full Load	Half Load	No Load	Load	Load
Kind of gas used Natural Gas.						
B. T. U. per cu. ft. gas at 30" Hg. and 62° F 990 Total	--------	- 905 Effective				
Barometer	29.15	29.15	29.15	29.15		
Pressure of gas at Meter	7	7	7	7		
Temperature of gas at Meter	70° F	70° F	70° F	70° F.		
Brake Circumference	32.8	32.8	32.8	32.8		
Total Weight on Scales	954	834	469	222		
Dead Weight on Scales	99	99	99	99		
Net Weight on Scales.	855	735	370	123		
Speed, (rev. per min.)	239	241	244.5	247		
Time of Start	21-13	53-40	47-18			
Time of Finish.	43-50	75-19	71-03			
Duration of Test.	22.55	21.65	23.75			
Meter Reading at Start	3300	2400	4200			
Meter Reading at Finish.	4100	3100	4700			
Gas According to Meter	800	700	500			
Gas per hour According to Meter	2130	1940	1262			
Gas per hour Corrected to 30" Hg. at 62° F	2085	1900	1238			
Brake H. P.	203	176	90			
Cub. ft. of gas per B. H. P.	10.3	10.8	13.75			
B. T. U. per B. H. P. Effective	927	978	1245			

REMARKS.

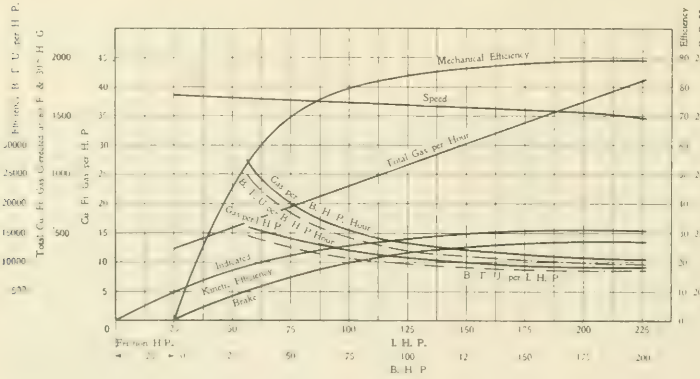
Average Friction H. P. of Engine = 25.
Mechanical Efficiency at Full Load = 87.2 %

SIGNATURES OF TESTERS.

W. P. Flint.
S. Dadley
N. C. Wilson

this instance a very fine performance. It will be seen from this that the curve of total gas consumption is nearly a straight line, while the curve of gas per horse-power differs somewhat from that of the corresponding curve of steam consumption in the steam engine, inasmuch as it indicates a progressive lower consumption up to the ultimate capacity of the engine. In this test natural gas was used, averaging 990 total, and 905 effective, British Thermal Units per cubic foot. At full-load the heat consumption is approximately 9800 British Thermal Units per brake-horse-power. The mechanical efficiency of the engine at this load is 87.2 percent and the kinetic or useful efficiency, based upon these figures, something over 26 percent.*

It is often stated that the efficiency of the gas engine cycle may be very remarkable and unapproachable by other forms of heat engines, but that it cannot compete with other prime movers at light loads. This argument certainly cannot be sustained in the case in hand, for even at half-load the useful kinetic efficiency is over 20 percent—very much above the efficiency of any steam engine at its most economic point. The efficiency drops very rapidly from this point of the curve to no-load, but even when the engine is developing 30 horse-power or only 6 percent of its rated capacity, a kinetic efficiency of 10 percent is obtained, which represents very creditable high class steam engine performance at full-load.



PERFORMANCE CURVE OF 175-HP GAS ENGINE

$$*\text{KE}=\frac{2545 \times \text{mechanical output in hp.}}{\text{B. T. U. input in the gas.}}$$

With the development of the higher-powered internal combustion engines for exclusive use with producer and other "lean" gases, it has become necessary to have a producer plant available for making tests with a gas similar to that upon which the engine is intended to run in service In order to meet this condition an elaborate gas plant has been installed and a number of tests made upon engines in connection with it. This adjunct to the testing facilities has proved of great benefit and of special interest on account of its novelty for work of this character. Already tests have been conducted which show a duty of less than one pound of coal per brake-horse-power-hour.

SOME TRAFFIC PROBLEMS OF THE DAY

By CALVERT TOWNLEY

GENERALLY speaking, every large city has congested districts where the limit of railway service to the public—as well as the limit of railway receipts—is the number of cars that can pass in a given time. With the maximum size of car soon reached, the maximum speed and minimum headway fixed by provisions for safety and other physical conditions, and the number of stops by the distribution of the population, this maximum number of cars that can pass is soon determined. Locomotive-hauled trains, of course, permit a material increase, but at a reduced schedule speed due to lower acceleration when starting, and with the further handicap that a locomotive is designed to haul a specified number of cars and is, therefore, more or less of a misfit for every other number. In addition, it lacks much of the convenient flexibility found so valuable in single units. The production of a multiple unit system, however, has permitted the operation of trains in all essentials as single cars are operated, thus combining the advantages of both. The elevated system in New York City furnishes a good example of what these advantages mean Equipped with locomotives as heavy as the structure would permit, twelve miles per hour was about the maximum schedule speed that could be maintained with the maximum number—five—cars in a train. Since train control has been installed six-car trains easily make fifteen miles per hour, a total car mileage increase of just fifty per cent per train, and that, too, with a greatly decreased cost of operation.

With this possibility of improved service and bigger dividends as attractions it is not surprising that train control has been adopted successively in Chicago, Brooklyn, Boston, New York, London and Paris for elevated or underground service as well as for general interurban traffic in many smaller places. It would, in fact, be hardly too much to say that train control is now generally accepted as the standard method of operating electric trains, and that no railroad hereafter to be equipped can afford to ignore its claims.

While city train service is the most obvious and has been the first application of train control, such service by no means covers the limit of its possibilities. It has already been discussed for electric locomotives to displace steam for the terminal and suburban service of some of our largest railroads, the function here being both to handle heavier currents than can be taken care of by previous methods and to permit the use of smaller locomotive units. These units, designed to haul local trains and the lighter expresses also, may be coupled in suitable numbers for the ponderous limited and other superlative duty.

Another application as yet purely speculative is that of street car service in congested centers. The demand for a means to increase the volume of traffic is certainly sufficient to warrant the most earnest effort, and with train control's remarkable record in improving heavy service conditions as an object lesson, it would be unwise to predict failure in this no less important direction.

Considered in all its aspects, train control is perhaps one of the most interesting and valuable of the many late electrical developments. Its influence on transportation problems has been far reaching and its future is fraught with great possibilities.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

VI—GENERATORS

By V. KARAPETOFF

A Series of Lectures Delivered before THE ELECTRIC CLUB

THE REGULATION OF ALTERNATORS

In alternators, as in transformers, the problem which may be most appropriately solved by means of vector diagrams is that of regulation. Fig. 45 shows the fundamental vector diagram for a loaded alternator which, as will be seen, bears a very close resemblance to that of a transmission line or of a transformer. In this figure, $O\ A$ is the induced e.m.f. or voltage at no load; $O\ C$ is the current, $B\ D$ and $D\ A$ are, respectively the ohmic and the inductive drop of the machine, $B\ D$ being parallel to $O\ C$ and $D\ A$ at right angles to $O\ C$, consequently $O\ B$ is the terminal voltage of the machine. A corresponding diagram for a lower power-factor, but the same current is shown in dotted lines. It will be readily seen that the effect of the drop on the terminal voltage of the machine is greater, the lower the power-factor, for the same current value, i. e., $O\ B_1$ is less than $O\ B$. If a constant terminal voltage is desired at every power-factor, the field current must be increased with an increase in the angle of lag. This is very much the same as in the case of a transmission line, or transformer, as has been explained. (June Issue, Pg. 284) and, so far, the alternator diagram is analagous to the other diagrams.

The great practical difficulty in the application of this diagram lies in the determination of the value of the inductive drop, and of the e.m.f actually induced in the armature windings, as influenced by the magnetizing effect of armature reaction on the field. The following is an investigation of the methods used to overcome these difficulties.

As has been already explained, (April Issue, Pg. 165,) the inductive resistance of a line, or transformer, for a given current can be easily found by short-circuiting the line, or transformer, and ascertaining the terminal e.m.f. which is necessary to produce the required current. That this does not apply in the case of an alternator will be easily seen if it is remembered that the field in the magnetic circuits is due to the resultant of the magnetizing force of the field windings and that of the armature windings. What actually happens is that the field of the machine induces currents in the armature, and these currents react upon the field, weakening it if the current is lagging, strengthening it if the current is leading. As alternators in practice are almost invariably run with lagging current, it will be necessary to consider only the case of a weakened field. The e.m.f. actually induced corresponds, not to the original field, at no load, but to a weaker field. This induced e.m.f. is further diminished by the ohmic and inductive drop in the armature just as if the armature were a choke coil through which the current had to flow before reaching the terminals of the machine. There are thus three causes for the drop in an alternating current synchronous generator or motor.

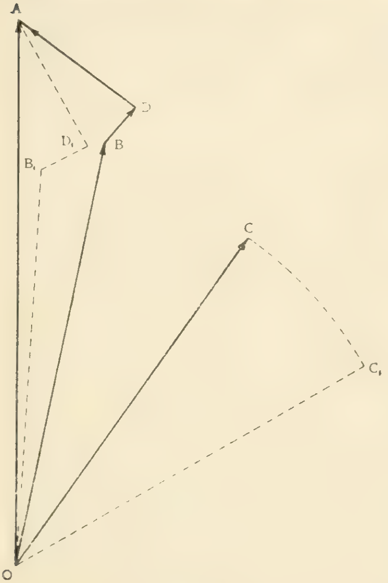


FIG. 45

(1) Ohmic drop.

(2.) Inductive or "reactance drop."

(3.) The demagnetizing effect of armature reaction upon the field.

The ohmic drop is represented in the usual way, by a vector parallel to the direction of the current and equal to ri. No reliable general method has yet been given to predetermine, or even to determine experimentally, the effect of armature reaction, apart from that of the armature self-induction. It has therefore become the practice, from want of any better method, to ascribe the total drop in the machine not due to ohmic resistance, as due either to *an equivalent self-induction*, or to an *equivalent armature reaction*, each comprising both causes of drop. We shall now investigate the legitimacy of these two compromises.

Equivalent Self-Induction and Armature Reaction.—In Fig. 46 let $O\,C$ be the current, $O\,B$ the terminal e.m.f., $B\,D$, parallel to *O C* the ohmic drop, *D A* the true reactance drop of the armature, perpendicular to *O C*, *O A* the e.m.f. actually induced in the armature. The real magnetic flux in the machine, which induced *O A*, leads *O A* by 90 degrees and is represented by the vector *O F*. Neglecting hysteresis, the actual ampere-turns *O K* are in the same direction as *O F*, and are equivalent to the resultant of the field ampere-turns *O I* and the armature ampere-turns *I K*, *I K* being parallel to *O C*.*

Thus, it will be seen that the field ampere-turns *O I* and the ampere-turns of armature reaction combine to produce a resultant number of ampere-turns *O K*. To this resultant excitation corresponds the actual magnetic flux *O F* which induces the e.m.f. *O A*. The actual terminal e.m.f. is less than *O A* by the amount *D A* of the reactance drop, and *B D* of the ohmic drop.

In testing a machine, the only quantities in Fig. 46 which are known or can be found are the current, the exciting current, the voltage at no load corresponding to any exciting current, (no-load saturation curve) and the ohmic drop. Neither armature reaction *I K* nor reactance drop *D A* can be determined separately by any known experimental method. Hence the diagram in Fig. 46 cannot be constructed unless an additional assumption is made, namely, *that the permeability of the iron is constant within a wide range of flux densities, so that fluxes are proportioned to ampere-turns.* Using this assumption, the triangle *O K I* of ampere-turns can be taken, to a different scale, as a triangle of fluxes, and a corresponding triangle *O A L* of e.m.f. can be constructed similar to the triangle *O K I* and lagging 90 degrees behind it.

This diagram may be interpreted as follows: The field ampere-turns *O I*, induce the total e.m.f. *O L*; the armature reaction induces the e.m.f. *L A*, the self-induction, an e.m.f. *A D* and the ohmic resistance an e.m.f. *D B*. Hence the remaining e.m.f. representing the terminal voltage, is *O B*. As both *L A* and *A D* are in the same direction, it may be said that the total drop is the resultant of the drop *L D*, at right angles to *O C*, and *D B*, parallel to *O C*. It is thus unnecessary to separate the drop produced by

---

*This construction presupposes that both the exciting field *O I*, and the field of armature reaction *I K*, have the same velocity in space, so that their relative position is always the same, and they can be added or subtracted as vectors. This is true for polyphase machines, because in these a synchronously revolving field is produced by the armature current. In a single-phase machine, the exciting field is revolving and the armature-reaction flux is simply pulsating. In this case the interaction of the two fluxes cannot be represented by a vector diagram, and can only be found by an analytical process of integration of instantaneous values (See G. Kapp's Dynamos, chapter on armature reaction). It has been shown by experiment, however, that armature reaction is not important in single-phase generators, the greater part of the total drop being produced by armature self-induction. Hence, Fig. 46 may be assumed to represent approximately the conditions in single-phase machinery.

armature reaction from that produced by self-induction as it may be assumed that the whole drop *L D* is produced by one equivalent cause:—either by an equivalent self-induction or by an equivalent armature reaction. As will be shown below, the total vector *L D* can be easily determined experimentally and the diagram *O L D B O*, thus determined, is perfectly correct as long as the saturation curve is a straight line; that is to say, as long as the triangle *O K I* of ampere-turns can be assumed to be also a triangle of fluxes. Unfortunately, however, the most important points on the saturation curve, which occur in practice, lie near and often above the bend, affecting greatly the applicability of the diagram.

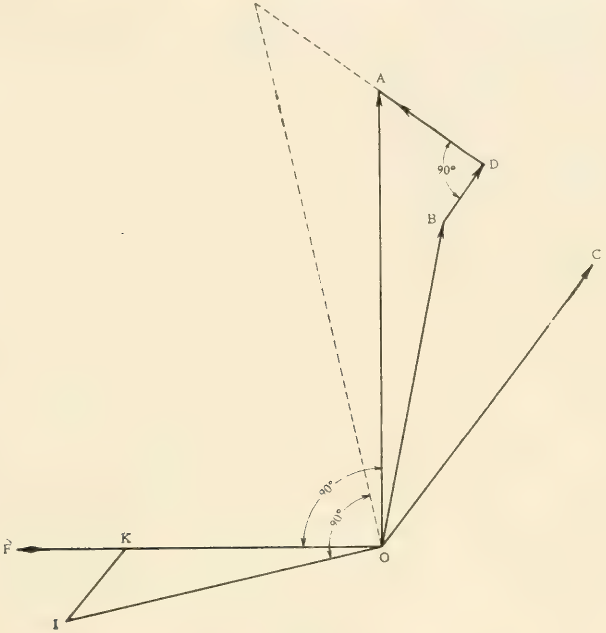


FIG. 46

Short-Circuit Test.—The following are the two experimental methods of determining the vector *L D* and the drop in the machine, for a given current, from the results of a short-circuit test.

In Fig. 47, *O L* is the no-load saturation curve and *O T* is the curve of current, or short-circuit, for different field currents. Let CC_1 represent the value of current for which it is desired to determine the drop, and let *F L* represent the normal voltage at no load. Two different methods of obtaining approximate load saturation curves are possible:

(1.) *The Armature Reaction or the Ampere-Turn Method.*—According to this method, $O\ C$ represents the total number of ampere-turns necessary to drive the current $C\ C_1$ through the armature, i. e., $O\ C$ is the value of the total drop $L\ D$ (Fig. 46). The angle between $O\ B$ and $L\ D$ (Fig. 46) depends on the power-factor for which the drop is to be found. We shall assume in Fig. 47 a power-factor of zero. There are two reasons for this choice:

(a.) At power-factor zero, the drop for a given current is higher than at any other power-factor and it is desirable to know the behavior of the machine under the most unfavorable condition.

(b.) At power-factor zero, the vector representing the drop $L\ D$ is almost parallel to $O\ L$ (Fig. 48), so that $L\ D$ can be subtracted algebraically from $O\ L$ instead of geometrically. This simplifies the construction and allows the ohmic drop $B\ D$ to be neglected. Thus, by this method, $O\ C$ represents the number of ampere-turns required to overcome armature reaction (including self-induction). This has to be subtracted from the total field amperes $O\ F$ in order to obtain the ampere-turns, $C\ F$, effective in inducing the voltage across the terminals. Hence, if we make $K\ F$ equal to $O\ C$, we obtain the terminal e.m.f. $K\ M = F\ D$, (with armature current $C\ C_1$ and power-factor zero), instead of $F\ L$ which was the value at no load. Similarly, if $M_1\ D_1$, $M_2\ D_2$, etc., are drawn, each equal to $O\ C$, a curve $C\ A$ will be obtained for the saturation curve with current $C\ C_1$ at power-factor zero. The vertical distance between the two curves gives the drop in the machine at different excitations.

(2.) *The Self-Induction or e.m.f. Method.*—According to this method an excitation $O\ C$ is necessary to drive a current $C\ C_1$ through the armature on short-circuit. This excitation would produce on open-circuit, an e.m.f. $C\ S$, which at short-circuit, is altogether lost in the armature, in driving the current $C\ C_1$ through its self-induction, (including armature reaction and ohmic resistance). Hence, $C\ S$ represents the total drop in the armature for the current $C\ C_1$. Subtracting $L\ B$ ($=C\ S$), from $F\ L$ we get the terminal voltage as $F\ B$. Plotting $L_1\ B_1 = L_2\ B_2$, etc., ($=C\ S$), we get another load saturation curve, $C\ A_1$. It will be easily seen that as long as the no-load saturation curve $O\ L$ is a straight line, both curves $C\ A_1$ and $C\ A$ coincide. Thus, for example, for an excitation $O\ F_3$ subtracting the voltage $D_3 L_3$ ($=CS$.) from $F_3 L_3$, or subtracting the excitation $M_3 D_3$ ($=OC$) from OF_3 gives the same terminal voltage $F_3 D_3$, because the triangles OSC and $M_3 L_3 D_3$ can be assumed similar. As soon, however, as the no-load saturation curve begins to drop, the curve CA_1 will lie below CA.

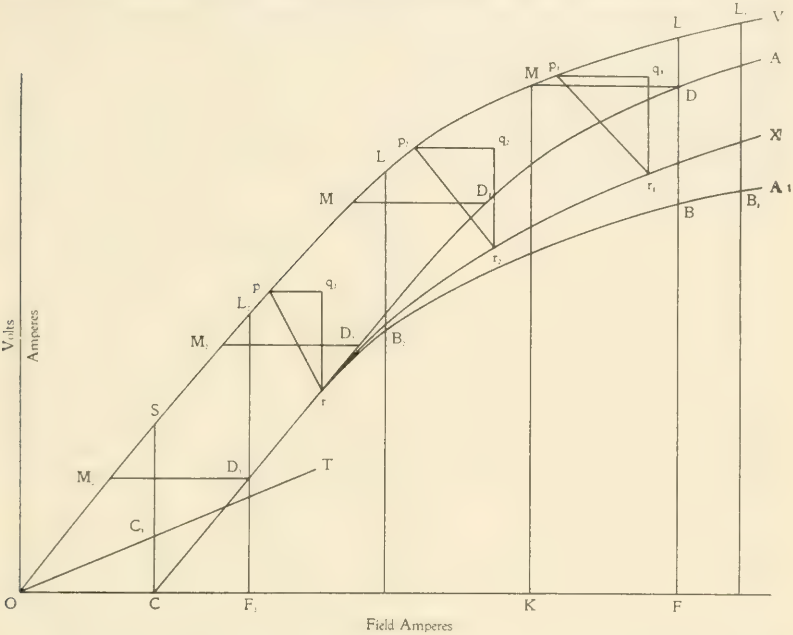


FIG. 47.

In reality both causes of drop, viz., armature reaction and self-induction, are always present so that the actual load saturation curve CX, taken from a test under running conditions, lies between CA and CA_1. In a paper, read before the American Institute of Electrical Engineers, Mr. Behrend called the first method, the "optimistic method" and the second method the "pessimistic method," for reasons which are obvious.

It is then an easy matter to plot both optimistic and pessimistic curves, from the results of no-load and short-circuit readings, in the manner described above. These curves determine the lower and upper limits of the drop and regulation of the machine. For machines of poor design, with large armature leakage, and also for single-phase machines, whose armature self-induction is prominent the actual load saturation curve will lie nearer to the pessimistic curve. For well-designed machines, on the other hand, especially for polyphase generators with armature windings distributed in many slots, (these slots being preferably open), with a strong exciting field in comparison with that of the armature reaction, the load saturation curve lies nearer to the optimistic curve.

Mr. Behrend very lucidly demonstrates the relation between the no-load saturation curve and the full-load saturation curve CX, by plotting the triangles $p_1 q_1 r_1$, $p_2 q_2 r_2$ etc. The sides $p_1 q_1$, $p_2 q_2$, etc., represent the true armature reaction. In order to find the point r, corresponding to the point p, on the no-load saturation curve, first add the number of ampere-turns $p_1 q_1$ corresponding to the armature reaction, then subtract the inductive drop $q_1 r_1$, finding the point r on the load saturation curve. This construction corresponds to the procedure in Fig. 46. Since, however, we have no reliable method of obtaining, separately, the armature reaction $p_1 q_1$, and the armature induction drop $q_1 r_1$, since the triangle $p_1 q_1 r_1$ cannot be determined, this method cannot be applied in practice.

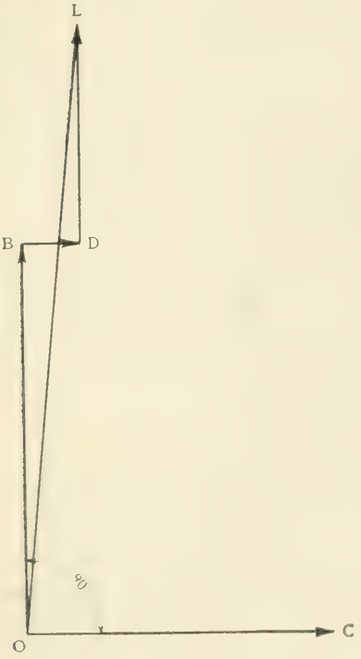


FIG. 48

In reality it is not so difficult, as it may seem from the foregoing, to predetermine the regulation with considerable accuracy. Every designing engineer who has had experience from the results of tests on similar machines, etc., has a good idea of what is to be expected of his machines. Even for new designs, empirical rules which he may have devised for his own guidance, and comparison with previous machines are generally sufficient to help him in predetermining the drop in his machine with an accuracy which is often surprising.

This does not, however, diminish the necessity for a good shop method of testing large alternators under conditions approximating those under which the machine is to be run in service. The regulation of a machine, especially under inductive load, is often inserted in the contract, and as it is in most cases impossible to test very large machines under full-load conditions, a method is very desirable which would satisfy both manufacturer and customer as to what is to be expected of the machine under service conditions.

Drop and Regulation From Actual Load Test.—In some cases it is possible to determine the drop and regulation of the machine by actual load test. Thus, smaller machines may be loaded on wire rheostats, water resistance, choke coils, unloaded transformers, large induction motors running without load, etc. If the drop and regulation for any power-factor are known, they can be determined for any other power-factor, with fair accuracy, by means of a diagram similar to that shown in Fig. 48. The length $L\ D$ is the same for all values of power-factor with the same current OC, but it varies in direction depending on the angle of lag between the current and the e. m. f., being always at right angles to the current. Consequently, we get the same Kapp's diagram as the one explained in Fig. 32 (June Issue, Pg. 284). In this way the necessity of separating armature reaction from self-induction is obviated and the total drop determined from actual test. It will be noticed that *it is desirable to have this load performed at as low a power-factor as possible, for the following reasons:—*

(1.) This means a full volt-ampere output with a comparatively small expenditure of motive power.

(2.) It is important for the accuracy in the determination of the drop vector LD_1. This vector is the geometrical difference between no-load and full-load voltages. On a high power-factor, this difference is small, and a small error in reading the voltmeter may introduce a considerable error in the determination of the drop. If this inaccurate value is then applied to find the drop or regulation at a low power-factor, where its magnitude is of greater importance, it may give very inaccurate results. On the other hand, the drop can be determined with much greater accuracy at a low power-factor, and any error in its determination is of less importance at higher power-factor deductions. (Fig. 14, April Issue, Pg. 166,) It will be seen in this figure that an error in the determination of inductive drop is of much greater importance at a power-factor of 100 per cent than it is at zero power-factor.

The following is an application of the method used in determining the drop and regulation at any power-factor if these are known for any other power-factor.

Example.—A 100-kw, 3-phase, 2,200-volt machine is loaded on combined ohmic and inductive resistances, so as to give the full rated current of 26.3 amperes per phase. The exciting current is held constant at the value which gives full rated voltage at no load and at full speed. The results are 1,801 volts terminal e.m.f at a power-factor of 42 percent. The average ohmic resistance from terminal to terminal is known to be 1.94 ohms at a temperature of 50° C. It is required to construct for this machine Kapp's diagram from which to find the drop and regulation at any power-factor. First of all it is necessary to reduce the output of this machine to its equivalent single-phase machine of the same voltage. Its current at full load will be $26.3\sqrt{3}=45.5$ amperes, and its ohmic resistance $=\frac{1.92}{2}=0.97$ ohms. In Fig. 49, with *O* as center, describe a circle *AB* with a radius=2,200 volts, and a horizontal line *OA* through its center. Calculate the ohmic drop, 45.5x0.97=44.1 volts, and draw *CD* =44.1 volts parallel to *OA* at a distance *OC* from *OA*. From any convenient point *F* on the line *CD*, draw a line *FG* making, with the vertical line *OB*, an angle corresponding to a power-factor of 42 percent. Measure off *FG*=1,810 volts and draw *GH* parallel to *OA* and intersecting the circle at *H*. From *H* draw *HK* parallel to *FG* cutting *CD* at *K*. The triangle *OKL* is then the familiar triangle of drops in the machine, *KL* being the ohmic drop and *OL* the inductive drop. *KM* parallel to *OB* is the direction of the current vector and it will readily be seen that at a power-factor of 42 percent the diagram actually gives a terminal voltage of 1,810. The semicircle *KPN* described on the diameter *KP* to such a scale as to make *KP* readily divisible into 100 parts, is the familiar circle of power-factor; and terminal voltage at different power-factors and at full load currents, are represented by vectors drawn from the point *K* to the circle *AB*. Thus, for instance, at a power-factor of 85 percent, we find the terminal voltage *KQ*=1,920 volts and, for non-inductive load, *KQ* =2,100 volts. In order to find the regulation of the machine, a second circle must be drawn with center *K* and radius equal to 2,200 volts, as has been shown in Fig. 36, (Aug. Issue, Pg. 414).

Larger machines can sometimes be conveniently tested by loading them on synchronous motors, running without load. In this test, the well-known property of the synchronous motor in taking a current which lags more and more, the less the excitation, is made use of. The working component of a synchronous motor running on no load is expended in covering the copper, iron and friction losses of the machine, and the wattless component can be made very great by lowering the excitation of the motor as far as stability of running, or the heating of the armature, will allow. It is quite possible, with a motor of about the same size as the generator to be tested, to obtain a power-factor of 20 percent, or even less. From the value

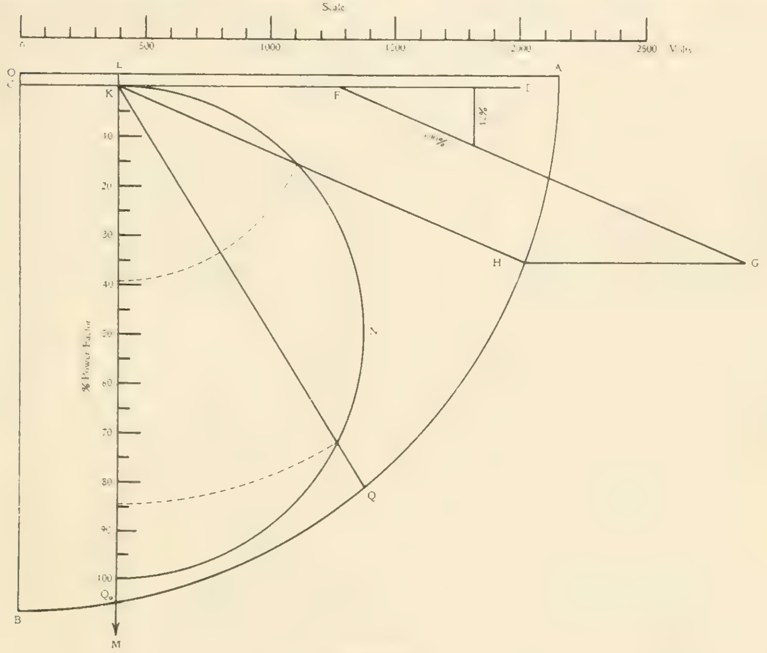


FIG. 49

obtained from this test, the drop and regulation at any power-factor for the same current are to be obtained by means of a diagram similar to that in Fig. 49. If it is required to determine drop or regulation at a fractional load, say at three-quarters or at half-load, the same diagram, Fig. 49, may be used for rough calculation, reducing the triangle *K L O* proportionately to the value of the current, as both ohmic and inductive drops are proportional to the current. Where greater precision is necessary it is preferable to make a separate test for each current value at which the regulation is required, as the equivalent inductive resistance of the machine changes with the armature current. This is due to the fact that the resultant saturation in the iron is higher at a fractional load than at full load, the field excitation being constant. Hence, the inductive resistance is less at a fractional load and greater at an overload, than it is at full load. Thus, if the triangle *OKL* is taken as proportional to the value of the current, a greater drop is obtained than that which actually occurs.

FACTORY TESTING OF ELECTRICAL MACHINERY—IX

By R. E. WORKMAN

COMMERCIAL TESTS

COMMERCIAL tests are those made on machines of standard design, where the first machine of the type has been completely tested. They are made chiefly to locate faults in the manufacture of the machine, *i. e.*, to determine whether the machine is to be approved for shipment.

The tests made on direct-current machines of standard design are:

(1) Polarity.
(2) Iron loss and saturation (only in case of large machines.)
(3) Regulation.
(4) Temperature.
(5) Insulation.

Table II. in the introduction gives briefly, the way in which defects in manufacture show up in commercial tests.

The following description will explain the method of testing in greater detail:

(1) Polarity—The effect of a reversed pole in a series-wound or two-circuit armature will be a simple reduction of the terminal voltage and inability of the machine to commutate properly in every brush position. The reasons for this will be obvious if it is remembered that in following the winding from one commutator bar to the next the winding successively passes under all the poles.

In multiple-wound armatures where there is a reversed pole there is a section of the armature in which no e. m. f. is induced and there is therefore practically a short-circuit across the brushes, through this section. The effect of balancing rings will be to counteract the magnetizing effect of the reversed field coil and to improve the distribution of the field. If a trial is first made with the machine as a generator, self-exciting, and it is found impossible to make it build up, an attempt may be made to run it separately excited. If it is then found impossible to get it to run sparklessly, and if it becomes hot with no load upon it, it may be assumed that there is a reversed coil.

TESTS OF POLARITY

(a) *By Compass*—This test is made by passing an ordinary magnetic compass round the field, near the faces of the poles, and noting the reversals of polarity by the behavior of the needle as the compass passes from pole to pole. The test should be made with a weak current in the field windings, as, if it were made with a strong field, the polarity of the compass needle might be reversed and false readings obtained. In any case care should be taken not to bring the compass too near the pole.

(b) *With a Small Piece of Iron*—If a small oblong piece of iron is held in the hand between the poles of the magnet it will tend to take up a position in line with the lines of force of the leakage field. Hence, if the iron is held between two unlike poles, where the leakage flows from pole to pole through the air, the iron will tend to take up a position bridging the gay between the poles, each end being attracted by one of the poles. If, on the other hand, the two poles be alike, there will be no leakage field between the poles and if the iron is held in a radial position it will have no tendency to turn.

(c) *By running the machine as a generator short-circuiting successive field coils with a short length of cable and noting the effect on the terminal voltage.* (Applicable only to machines having series-wound armatures). In this test the field current is held constant by means of a rheostat in the field circuit and a reversed coil is indicated by a higher voltage when that coil is cut out and the field current brought back to its constant amount. A short-circuited field coil will be indicated by an unchanged voltage when the coil is cut out.

(d) *By observing the leakage in such parts of the machine as the ends of the shaft, etc.*—The effect is detected by noting the attraction of a small piece of iron by the end of the shaft, when it is held near it. Excessive leakage indicates want of symmetry in the field, which may be due either to a reversed or to a short-circuited field coil.

The case of a coil which is short-circuited on itself is much more insidious than that of a reversed coil, although it occurs much less often. It will not show up with the compass, since the pole affected is simply weaker than the others. The machine may commutate fairly well, but the voltage in the case of a generator, or the speed in the case of a motor will point to the nature of the trouble.

(2) Iron Loss and Saturation:

This test is made exactly as described under experimental testing.

(3) Regulation:

This test is made in exactly the same way as in the case of new types except that fewer points on the curve are taken; it requires no further description.

(4) Temperature:

Temperature tests in the case of standard machines are often made much shorter than is required to bring the machine to a constant temperature rise. The ultimate temperature rise is deduced from the shape of the heating curve from former tests. Otherwise the test is exactly the same as for new machines.

(5) Insulation:

Insulation tests are of two kinds:

(a) Those which depend upon the measurement of the resistance of the insulating material, considered as a conductor. All substances in some degree possess the property of electric conductance. This conductance depends very largely on the temperature of the insulation, on its dryness and on its surface dimensions. Tests made of this property simply measure the current passing through the insulation with a given difference of potential across it. Insulation resistance varies enormously with comparatively small changes in the condition of the insulation with respect to dirt and moisture. A test of insulation resistance therefore gives no positive indication of the real quality of the insulating material, but is very useful in gauging the condition of the material.

(b) Those which depend on the proof of the "dielectric strength" of insulating material. By the "dielectric strength" of an insulating material or its strength as a dielectric or insulator between two conductors differing in potential, is meant its resistance to actual mechanical puncture by a spark, destroying the continuity of the insulating surface. Dielectric strength depends very largely upon the physical properties of the material, *i. e.* its hardness, freeness from cracks, and pores, its thickness and also on its electric resistivity considered as a conductor. From the foregoing it is obvious that the test of insulation resistance only applies to a part of the essential properties of an insulator, so that, in itself, it is not complete. Hence the dielectric strength tests should always be made before a machine leaves the testing department.

(a) *Measurement of Insulation Resistance*—This test is usually made by placing the insulation across 500-volt direct-current lines, in series with a moving coil voltmeter of known resistance. The connections are represented diagrammatically in Fig. 44. Where the test is made on a circuit which may be grounded on one side, the machine tested must be set on wooden or other insulating supports. If this is not done a short-circuit may be the result. The current which flows through the voltmeter, and hence the deflection of the voltmeter, depends on the insulation resistance. The actual insulation resistance may be found from the voltmeter reading and voltmeter resistance as follows:

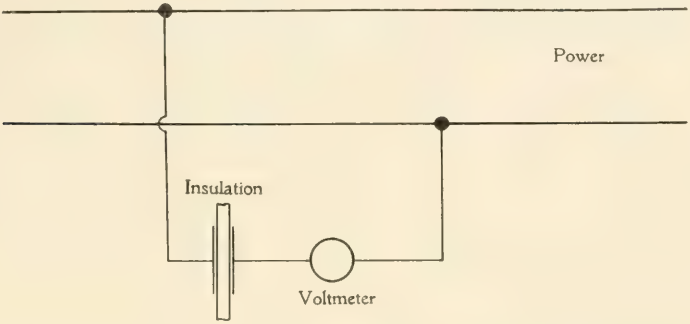


FIG. 44—CONNECTIONS FOR MEASUREMENT OF INSULATION RESISTANCE.

Let a = voltmeter resistance.

Let b = insulation resistance.

Let d = reading of voltmeter in series with insulation, with 500 volts across them.

From Ohm's Law it is obvious that the current in the voltmeter will always be, the reading divided by the resistance of the voltmeter.

In the test taken, the current in the circuit comprising the insulation and voltmeter is,

$$\text{Current} = 500 \div (a + b)\text{; also}$$

$$\text{Current} = (d \div a)$$

since d is numerically equal to the drop across the voltmeter.

Hence $500 \div (a + b) = (d \div a)$, and

$$b = a\left(\frac{500 - d}{d}\right) = \left(\frac{500}{d} - 1\right) \times a$$

As it is not generally necessary to know the actual insulation resistance, but only to compare it with that of other similar ma-

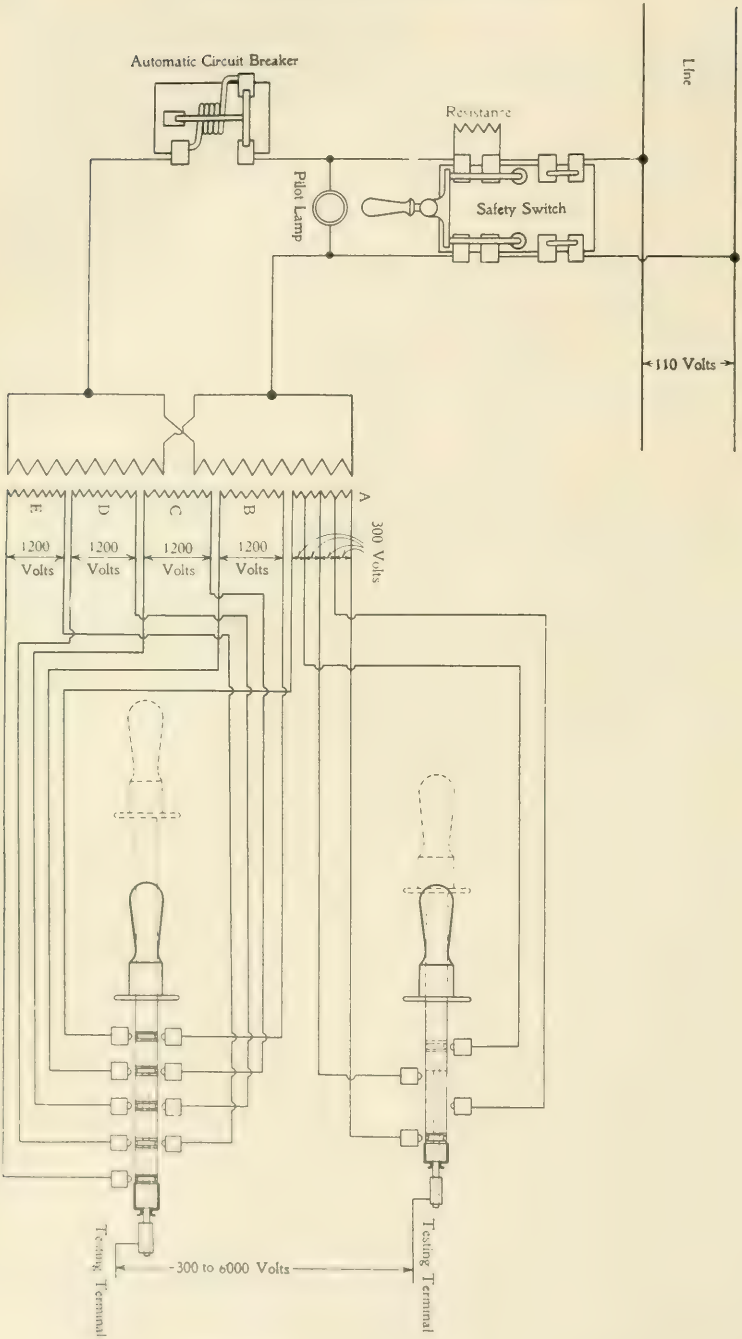


FIG. 45—CONNECTIONS OF 6000-VOLT INSULATION TESTING-SET

chines, it is generally sufficient to note the deflection of the voltmeter and, if that is satisfactory to pass the machine as ready for a test of dielectric strength. In many cases the principal reason for making the test of insulation resistance is simply to find whether the insulation is likely to be punctured in the test of dielectric strength. If the insulation resistance should prove to be too small the machine is sent back and examined and if necessary its insulation treated, before the test of dielectric strength is made. On machines of low voltage where the insulation may as a rule be trusted not to break down under the test for dielectric strength, the test of insulation resistance is seldom made.

(b) *Test of Dielectric Strength—Puncture Strength.* This test is made by means of a step-up transformer so connected as to give a range of high voltages. The connections of such a transformer in portable form are shown in Fig. 45, and in Fig. 46 is shown the outside appearance. In the primary circuit is a circuit-breaker and a double-pole switch, the circuit-breaker being adjusted to carry a current very slightly greater than the no-load current of the transformer. The low-tension leads are connected to the 110-volt, 25-cycle shop circuit by means of a lamp socket or hooks provided for the purpose in various parts of the testing department. The secondary leads are held on the parts, the insulation between which is to be tested. The secondary taps are, of

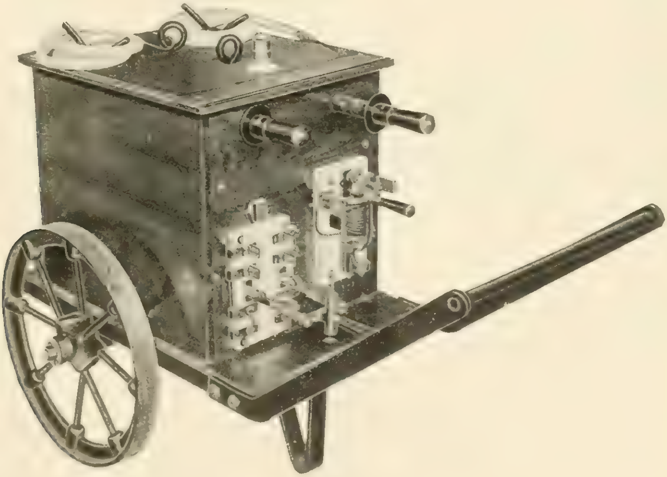


FIG. 46—6000-VOLT TESTING-SET

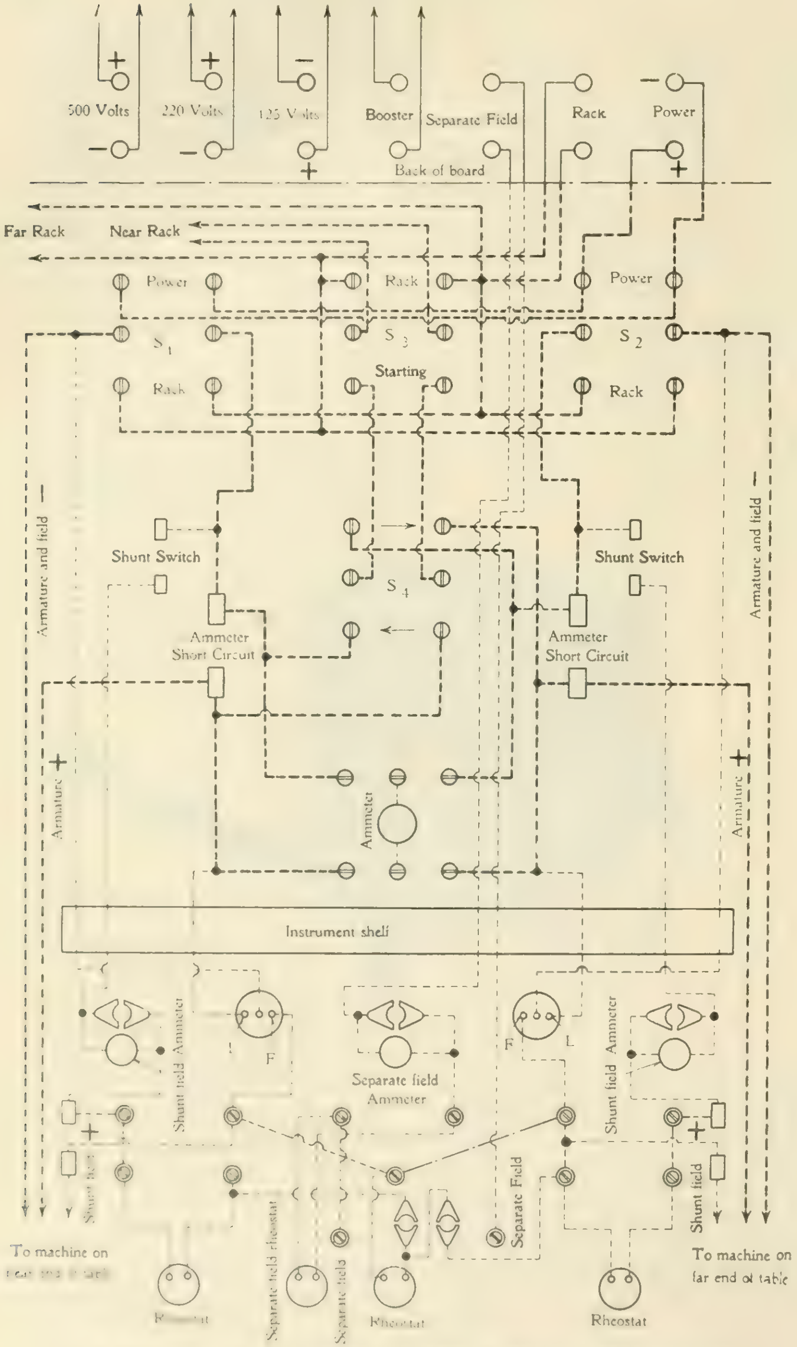


FIG. 47—TESTING SWITCHBOARD FOR SMALL DIRECT CURRENT MACHINE.

course, adjusted to give the desired voltage, and then the circuit breaker and switch are successively closed. If the insulation should break down the current in the primary would rise and throw the circuit-breaker. If, on the other hand, the insulation passes the test the circuit-breaker will not be thrown out. As a precaution it is well to touch the secondary leads together after each test to make sure that the circuit-breaker is working properly. These tests are generally made immediately after the temperature test, while the machine is hot. This is done because when the insulation is hot its dielectric strength is least and consequently the test is most severe.

COMMERCIAL TESTS ON SMALL MACHINES.

In the case of small machines up to about fifteen kilowatts, on account of the large number to be tested, a special equipment is required. The photograph facing page 169, Part III. of this series of articles, shows a view of the section of the testing department devoted to this work. Special tables set side by side are used to support the machines to be tested. On one end of each of these tables there is a slotted iron plate which can be moved in the direction of the length of the tables by means of a screw and hand wheel. The machine to be tested is set on the iron plate and another machine, generally one specially kept for the purpose, on the other end of the table and the two belted together. The tension of the belt is adjusted by means of the hand wheel. Near one end of each table there is a switchboard, whose connections are indicated in Fig. 47, having a shelf upon it for the instruments. At the back of this switchboard there is a rack of iron-wire resistance, divided into two parts, which may be used separately. The switches on each side of the center line of this board are used for each of the two machines run. The method in which the board is used is as follows: If the machine on the end of the table next the switchboard is a generator, S_1 and S_3 should be thrown down and S_2 and S_4 thrown up. The motor field switch may then be closed and the motor started up, using the half of the rack next the switchboard as starting resistance. In starting up, the ammeter change-over switch must be on the generator side so that the ammeter short-circuiting switch on the motor side may be used to finally cut out the rack used for starting. In order to apply the load to the generator the switch S_3 should be thrown up and the generator field switch closed. The generator external current is read by throwing the ammeter change-over switch to the left and opening the short-circuiting switch on that side. The generator shunt current is read by pulling out the short-circuit plug marked "shunt-field ammeter." The terminal voltage is read across the left hand side of the voltmeter socket on the left hand side of the board. The field voltage is read across the right hand side of the same socket.

In starting a motor on the near end of the table S_1 should be thrown up and S_2, S_3 and S_4 thrown down. Otherwise the test is practically the same as in the case of a generator. Where another machine is available to make a double test, it is used in place of the shop machine.

Precautions to Be Observed—In plugging in the booster to obtain voltages other than those of the testing circuits it is necessary to follow a very definite system to avoid short-circuits. The connection used is shown diagrammatically in Fig. 48.

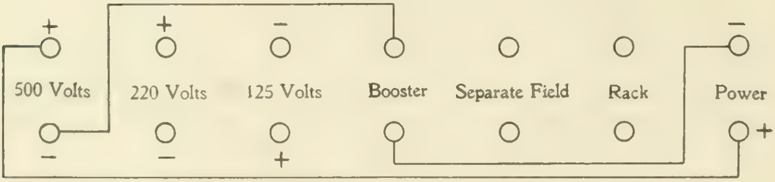


FIG. 48—BOOSTER CONNECTIONS WITH BOARD SHOWN IN FIG. 47

Where it is desired to measure resistance on the near end of the table with this board, the connections on the power board should be made as in Fig. 49. S_1 is thrown up and the current adjusted on the far rack.

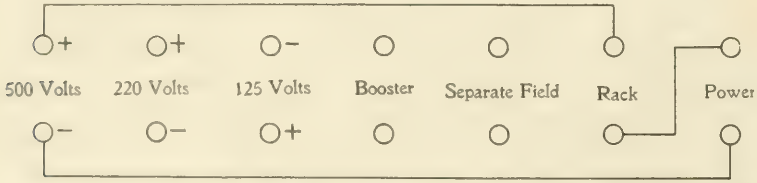


FIG. 49—CONNECTIONS FOR MEASURING RESISTANCE WITH BOARD SHOWN IN FIG. 47

As a rule, on small machines, only two points on the regulation curve are taken, that at no load and that at full load. Temperature tests are usually short, with an overload, the equivalent rise for a complete full-load temperature test being computed from previous tests.

COMMERCIAL TESTS ON SERIES MOTORS

The commercial tests on series motors are different in many particulars from those on shunt and compound machines. The ones principally met with are railway motors, and, as these are passed through in large numbers, a special equipment is used. The board found convenient for commercial tests on railway motors is shown in Fig. 50. The power board is on the back of the main board and comprises the line switches, booster switches and circuit-breaker as shown. Two motors are tested at the same time, being coupled together by means of a flexible coupling and one run as a motor driving the other on rack load as a generator. The motors are supported on heavy wooden trestles which can be drawn apart so as to uncouple the motors. The connection of the motors is shown diagrammatically in the figure. R_1 and R_2 are double-throw double-pole switches for reversing the connection of armatures of the motors, and thus their direction of rotation. There is one power board for every two testing boards and the same controller and ammeter are used for both testing boards, being connected to special bus-bars for that purpose. The connections shown in the figure are those for running No. 2 as a motor. The motor is started by closing the ammeter switch and the starting switch and then cutting out the controller resistance. When the speed is up the running switch is closed. The starting switch may then be opened, and, if desired, another set of machines started up from the testing board. In order to take current readings on No. 2 the controller resistances should be on the full running position, the starting switch closed and the running switch opened; the current may then be read by opening the ammeter switch. There is a special arrangement for making the test of insulation resistance. One pole of a small 500-volt generator kept for the purpose is connected to the frame of each of the motors in succession, by means of the switches shown; at the same time a voltmeter is placed in series with the insulation between windings of the motor and the other pole of the generator. The special generator is necessary owing to the fact that the 500-volt testing circuit is liable to frequent grounding.

ORDER OF TESTS MADE ON RAILWAY MOTORS

(1) Dielectric strength. (In the case of motors over 500 volts).

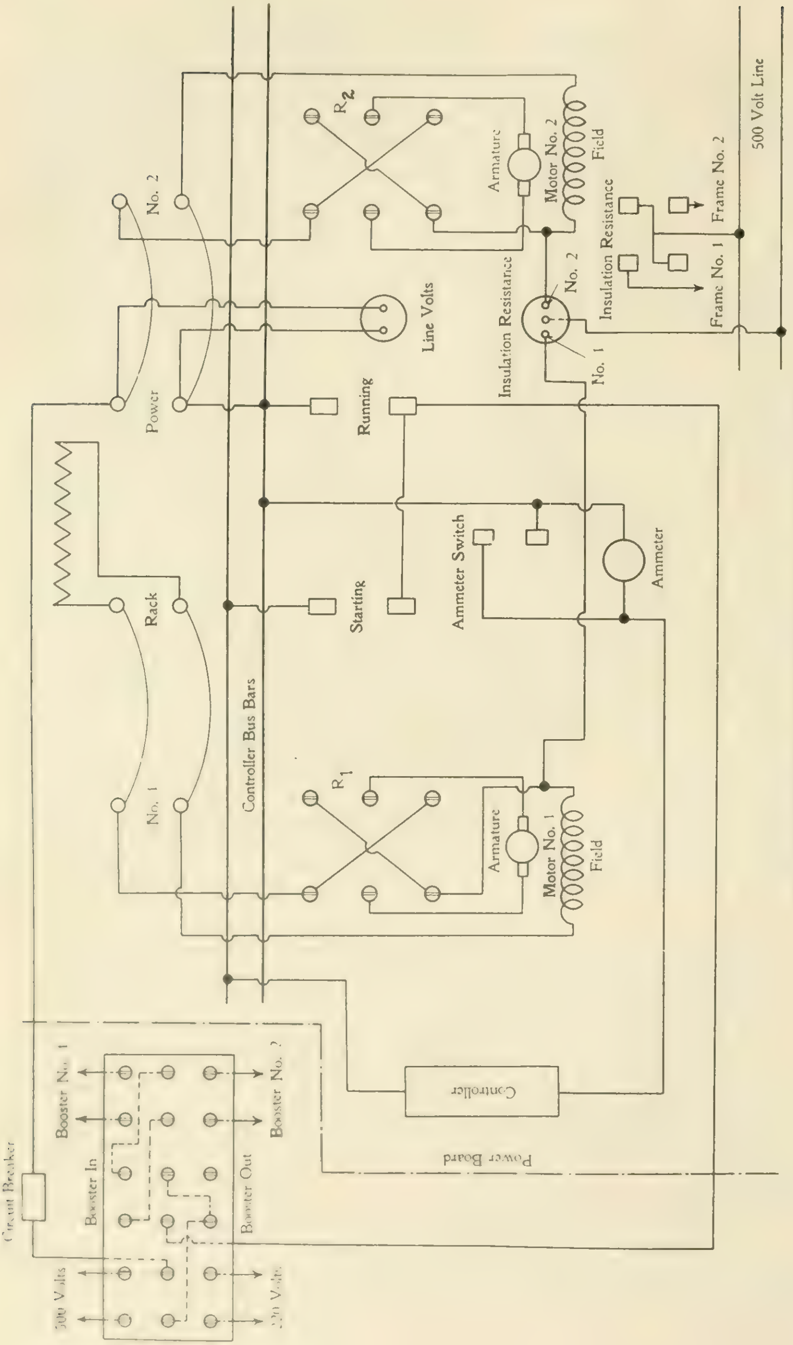


FIG. 50— TESTING SWITCHBOARD FOR RAILWAY MOTORS

(2) Two motors connected to the power in series, so as to oppose one another's rotation, three-quarter full-load current passing. The intensity of the current is regulated by putting the rack in series with the power. This test is made to find whether the field polarity of the motors is correct, as if that were wrong the motors would not hold one another. It also determines the connection of the field for which one motor will run as a motor and the other pick up as a generator. A reading is taken of the field drop in voltage on each motor.

(3) Readings are taken of terminal e. m. f., current, field volts and speed, on both machines, acting in turn as motors, at three-quarter load and with clockwise rotation. The two machines are then run for one-half hour with No. 1 as motor, on three-quarter load and with clockwise rotation.

(4) The following series of readings is taken after this run as quickly as possible—terminal e.m.f., current, field volts and speed. speed.

With No. 1 as motor, three-quarter load—clockwise.

With No. 1 as motor, three-quarter load—counter-clockwise.

With No. 1 as motor, one and one-quarter load—counter clockwise.

With No. 2 as motor, one and one-quarter load—counter-clockwise.

With No. 2 as motor, three-quarter load—counter-clockwise.

With No. 2 as motor, three-quarter load—clockwise.

(5) The set is then run for one-half hour, with No. 2 as motor on three-quarter load, clockwise.

(6) Readings of terminal e. m. f., current, field volts and speed, first with No. 2 and then with No. 1 acting as a motor, at three-quarter load and with clockwise rotation; after which the machines are shut down.

(7) Insulation resistance test.

(9) High-speed test.

(10) Dielectric strength test.

The high-speed test is used to prove the strength of the binding wires, commutator, etc. The motors are uncoupled and separated and then each is run for a short time at from 1200 to 2000 r. p. m. In order to gauge this speed the simple tachometer described in THE ELECTRIC CLUB JOURNAL for April, 1904, page 181, is used.

SHOP EXPERIENCE

ITEMS FROM THE NOTE BOOK OF THE APPRENTICE

TEST OF A POWER-FACTOR METER

EXTENSIVE tests recently made on a two-phase power-factor meter, show the readings of the instrument to correspond very closely with the calculated values. The instrument was connected up as shown, the load being a three-phase rotary converter connected across two-phase buss bars by phasing transformers, and having a variable resistance across the direct-current end. The load was varied by means of the resistance, real and apparent power measurements being taken by means of two Watt dynamometers, two voltmeters and two ammeters. The power-factor was varied by under or over exciting the rotary field thereby causing a lagging or leading current. When the generator used gave a current having approximately a sine wave, the readings of the instrument were found to agree very closely with the values calculated from the real and apparent watts consumed. A Stillwell regulator connected as shown was used to correct for any unbalancing of phases, the regulator being so adjusted that the voltage was the same across each phase. An ordinary unbalancing of the load has prac-

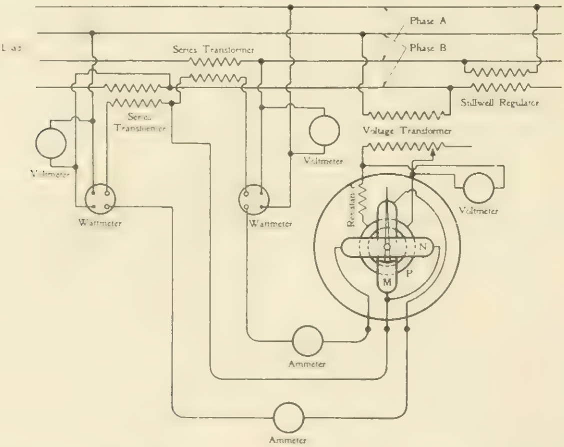


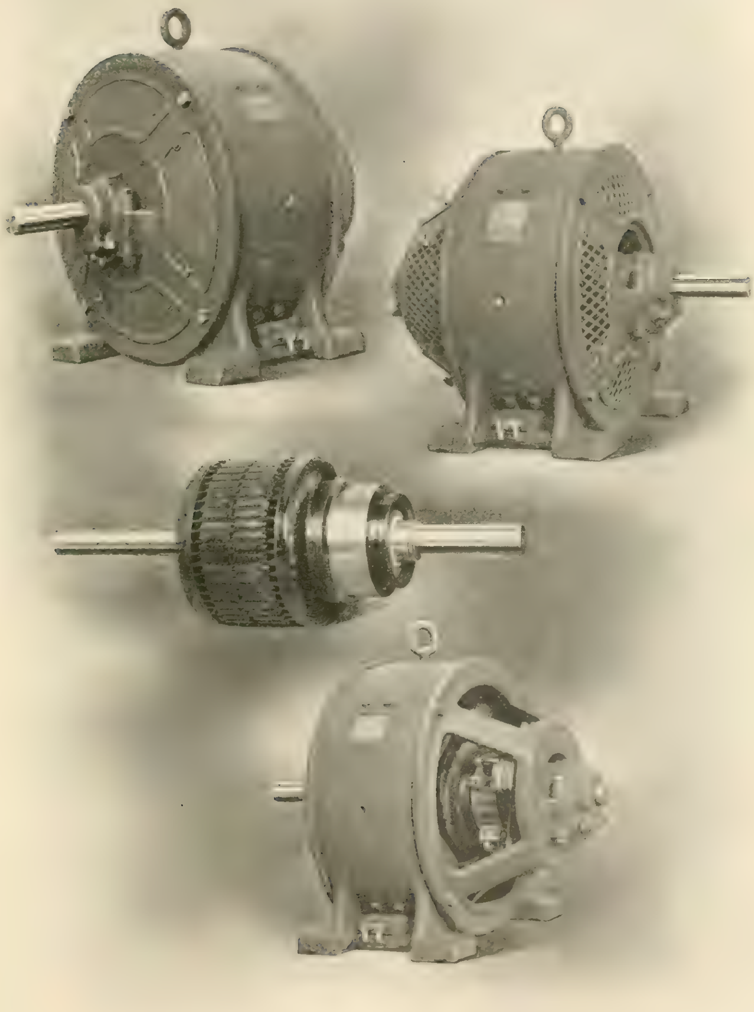
DIAGRAM OF CONNECTIONS USED IN THE TEST OF POWER-FACTOR METER tically no effect upon the readings; a violent unbalancing however, has some effect, and should be guarded against in taking very accurate measurements. In order to check both the upper and lower scales of the meter, a storage battery was substituted for the resistance across the direct current side of the rotary converter. By strengthening the generator fields, the converter could be made to charge the storage battery when the meter would give readings on the upper portion of the dial; or, by weakening the field of the generator, the storage battery could be made to furnish power to the converter, when the meter would give readings on the lower portion of the dial.

Correction for Change of Frequency in Power-factor Meter—By shifting the dial of a power-factor meter through a small angle, the instrument may be made to give correct readings for any frequency. For ordinary use, portable instruments are calibrated for 25 and 60 cycle circuits. A non-inductive load is applied sufficient to cause 5 amperes to flow through the series coils of the instrument, and by means of a regulating transformer, the voltage across the shunt coil is adjusted to 100 volts. This operation is performed using a 25 cycle generator, the dial of the meter being shifted so that the pointer rests over the 100 per cent power-factor mark, and a mark is placed on the dial opposite a finger fixed to the frame. 60 cycle current is then substituted for the 25 cycle, the dial again shifted so as to read correctly, and its new position marked. By interpolation, the instrument may be used on any frequency between the two chosen. The power-factor is, of course, checked by taking readings on Watt dynamometers, voltmeters and ammeters.

CORRECTING THE INDUCTION TYPE OF VOLTMETER FOR CHANGES OF TEMPERATURE

When the temperature of an induction type voltmeter having an aluminum disc revolving in the air gap of an electro-magnet, increases, the resistance of the aluminum disc is increased, thereby decreasing the current flowing in the disc, which reduces the torque on the disc and consequently the deflection of the pointer; the current flowing in the magnetizing coil of the voltmeter is hardly affected by change of temperature since the impedence of the coil is mostly inductive; therefore with increasing temperature, the current in the disc decreases, the current in the magnetizing coil remains constant and the readings of the instrument decrease. Two methods of correcting for change in temperature may be used depending upon the frequency for which the instrument is designed. Both methods consist essentially in increasing the strength of field to compensate for the decreased current flowing in the aluminum disc. In meters for high frequencies, having a large torque, a short-circuited coil is placed completely around one pole of the electro-magnet. Increasing temperature increases the resistance of this coil, which decreases the induced current flowing in it, which in turn decreases the choking effect of the coil on the magnetic field. The field strength will therefore increase with increasing temperature, giving the compensation desired.

In meters for low frenquencies, a non-inductive resistance is shunted around the magnetizing coil of the voltmeter; and the size of wire and method of winding used in this shunt are such that its resistance increases with change of temperature at the same rate as the resistance of the aluminum disc. Therefore, with increasing temperature, more and more current flows through the magnetizing coil of the voltmeter, thus increasing the field strength and giving the desired compensation.



MULTIPOLAR, DIRECT-CURRENT MOTORS. THE SEMI-ENCLOSED AND ENCLOSED STYLES ARE OBTAINED ON THE SAME FRAME THROUGH THE USE OF DETACHABLE COVERS

EDITORIAL COMMENT

The Tesla Motor and the Polyphase System

The types of alternating-current apparatus which are in use to-day have resulted from a process of evolution which has been going on for many years and in which the polyphase induction motor has been the fundamental element. The announcement of the polyphase induction motor and of the polyphase system were made by Mr. Tesla in 1888. The motor excited much interest and expectation. The polyphase system received little consideration. The motor, however, was helpless without a supply of suitable current. The alternators of that day were single-phase, they gave 120 to 133 cycles; alternators and transformers were ill adapted for supplying out-of-phase current. Persistent work, not only in the design and development of the motor but in that of the system as well was required before commercial success could be secured. In reaching this point it was not only necessary to overcome preconceived ideas of the public, but the electrical workers themselves had to unlearn, or at least readjust much of the information which they had acquired in connection with direct-current and single-phase alternating current apparatus and practice. In point of fact the Tesla invention was not merely a motor, but a system. Commercial men and engineers who did not understand the problems involved were naturally impatient and critical because the Tesla motor was not immediately supplied for operation upon existing circuits and in connection with the then prevalent types of generators. As a matter of history it is the Tesla principle and the Tesla system which have been the directing factors in modern electrical engineering practice. Alternators are now polyphase; they are of low frequency, they have close inherent regulation. All of the long distance systems for power transmission involving hundreds of installations, hundreds of thousands of horse-power and many millions of dollars of capital use the polyphase system. Nearly all of the great central stations for city railway and lighting service, even when the consumption circuits are supplied with direct current employ low frequency polyphase alternators. There is scarcely an important city or town in the country that has not a polyphase plant and polyphase apparatus is largely used for power distribution in industrial establishments.

This evolution has involved far more than the mere perfection of the motor. In fact polyphase motors as made prior to 1890 if operated in connection with modern generators would probably be more successful than the motors of to-day if operated in connection with polyphase alternators of the types first employed. The early polyphase alternators were small, they were of high frequency, they were of poor regulating qualities. Changes have been made in alternators and in transformers. Parallel operation of alternators has become a necessity, imposing exacting problems in the design and operation of steam engines. The extent to which everything in modern electrical power work has been affected by Tesla inventions makes it apparent that the polyphase motor which he proposed was no simple and isolated thing, but it was the central factor in a great and comprehensive system. The whole trend and evolution for the past sixteen years has been in the development of the polyphase system primarily that it may operate the polyphase induction motor. The realization of the Tesla invention was looked for simply in a motor to be forthcoming in a few months; it has come in an evolution of engineering practice which has been the work of years.

CHAS. F. SCOTT.

The International Electrical Congress

The International Electrical Congress held at St. Louis in September undoubtedly surpassed previous records in the number of electrical scientists and engineers which it brought together and in the number of papers which were presented and discussed. About one hundred and sixty papers, contributed by invited experts, were presented before the eight sections of the congress, which met simultaneously. The transactions of the congress will form a most valuable and comprehensive epitome of electrical ideas and practice at the present time.

Other congresses are on the program of the Louisiana Purchase Exposition which will deal with all phases of progress—material, social and intellectual. It is doubtful, however, whether any other congress deals with matters which have had a more rapid and extended development or are more far-reaching in their influence than those which are within the scope of the Electrical Congress.

And yet the Electrical Congress with its multitude of papers, domestic and foreign, did not bring forth anything startling or revolutionary. This is illustrated, for example, by the proceedings of the power transmission section. Scarcely a branch of electrical work shows a greater rate of development at the present time. There was not a high-voltage polyphase transmission line in this country at the time of the World's Fair at Chicago. Generally speaking the subjects presented dealt with matters which have become of consequence during the past five or six years. The future promises to witness a continued advance. But the papers and discussions were not speculative nor did they propose new and radical things. They dealt almost wholly with construction and operation, with materials and designs, with experiences and methods.

In a general way the work in this section of the congress was typical of all. The electrical world is interested in standards, in improvement of methods, in working out more efficient ways of doing things. The papers and the discussions and the friendly meeting together of engineers indicates an efficient co-operation among electrical men which is a distinct factor in effective progress.

Chas. F. Scott.

Electric Railway Braking

The article on Electric Railway Braking which appears in this issue of The Journal is the first of a series of articles on this important subject which we believe will be of interest to those directly connected with the operation of electric railways, and also to the vast traveling public whose safe transit so largely depends upon the efficiency of the car brakes.

The braking problem at once presents two points of view; the safety of the public and the increase in the earnings of the system.

An efficient and reliable braking equipment affords faster schedules and greater safety. A fast schedule not only means a directly proportionate increase in dividends but also greater satisfaction to the passengers who, as a rule, place considerable value on their time—often to the neglect of their own safety. Thus the two view points are in reality one. The efficient operator will look after the safety of his passengers as well as the road earnings, while the public is as much interested in fast schedules as the operator, though from a different reason.

The subsequent articles will cover the various types of air brakes. These differ in their methods of operation and in the source of the compressed air employed. The proper design of foundation brake gear, so essential to an efficient and reliable brake, will be discussed. The maintenance of brakes and the effect upon the operating schedule of the right and wrong ways of handling them will form another interesting problem. The development of the magnetic brake will be broadly treated, including its particular field of utility.

The series of articles will close with an historical sketch of the progress of the art of braking from its inception to the perfected types of to-day.

CLUB NEWS

Another season of social life among the members of The Electric Club was opened Saturday evening, October 1, with a smoker. Over two hundred members gathered at the club rooms, according a most hearty reception to the new men.

Instrument and voice of club talent furnished good music, which, with chorus singing of college songs in true smoker style, brought back many a memory of good old college days, and the evening went all too quickly.

Undoubtedly the hit of the evening was made by Blackmore and Baker with their bagpipes and Scottish dances. Much expression of fellow feeling was given through a great variety of college yells, with the result that two prizes were offered by Mr. C. F. Scott, one for the best Electric Club yell, the other for the best Electric Club song.

PERSONAL MENTION

A. E. Flowers has left the Company to take the position of instructor in Electrical Engineering at the University of Missouri, Columbia, Mo.

Charles H. Davis recently resigned his position as general manager of the Scientific Materials Company of Pittsburg to accept a position with the Nernst Lamp Company.

V. Karapetoff, author of the series of articles on alternating-current diagrams, now going through The Electric Club Journal, has been appointed Assistant Professor of Electrical Engineering at Cornell University.

Mr. John S. Peck will leave Pittsburg about the middle of the month to go to Manchester, where he will become Acting Chief Electrical Engineer of the British Westinghouse Electric and Manufacturing Company. Mr. Peck entered the Electric Company a little over ten years ago, shortly after graduation from Cornell University. After a short time on the Student Course, he took up engineering work in connection with transformer design. He soon became the head of the transformer designing work, which position he has held until the present time.

Mr. C. H. Darrall has left the Testing Department of the Electric Company to direct the laying out of the Testing Department at the new factory of the Canadian Westinghouse Company at Hamilton, Ontario.

INDUSTRIAL NOTE

A most artistic folio-catalogue has just been received by us from The William B. Pollock Company, Youngstown, Ohio.

All descriptive matter has been entirely eliminated save a brief introductory calling attention to blast furnace construction, also riveted pipe and steel chimney work. The folio is a work of art—contains sixty full-page halftones, done on heavy paper, forming a beautiful and comprehensive pictorial review of work erected by that company during the past five years.

WANTS

WANTED—A position by a young man who has a diploma in electrical engineering. Can furnish good references. Address C. W. Dickinson, 1008 Oak street, Elmira, N. Y.

WANTED—Your orders for technical books. A full line of the latest works on electrical and mechanical subjects. Liberal discount from current prices Chas. J. Baab, 415 Ross street, Wilkinsburg.

WANTED—Back numbers of THE ELECTRIC CLUB JOURNAL. I will pay 15 cents each for all March, April, May and June copies. W. T. Hardern, P. O. box 911, Pittsburg.

TRAIN OF METROPOLITAN WEST SIDE ELEVATED RAILWAY OF CHICAGO. THIS ROAD HAS RECENTLY ABANDONED STRAIGHT AIR BRAKES AND INSTALLED THE AUTOMATIC SYSTEM

THE ELECTRIC CLUB JOURNAL

VOL. I NOVEMBER, 1904 NO. 10

THE POINT OF VIEW*

By WALTER C. KERR

IT IS a pleasure to talk to a lot of young men who are about to become engineers. It was not so long ago that I came to your age less well prepared, perhaps, than any of you. When I look back at the engineering education through which men of my time were launched, and then consider the training you have had and the opportunities before you, I have reason to wonder why I am here.

I hesitate to advise you. You have already had so much advice that I do not know whether you can hold more. What I can say in a few minutes will amount to little, so let me use these minutes to suggest that you advise yourselves along certain lines which I will propose by way of point of view. If you look straight you will see straight. You cannot think wrong and act right. Your perspective will be distorted if you haven't the right point of view.

You are leaving a good institution for a good world. Your Alma Mater has built up around you excellent facilities for giving you what you need, and other institutions have likewise cared for their own.

The so-called liberal education has always been highly academic. Trade school engineering has been strictly non-academic. The two have joined hands fortuitously in our modern institutions. The liberal education has become less and the technical more academic, with advantage to both. There is, however, danger of engineering education growing too academic, for several reasons. One is the disposition to include in technical training a liberal education, which of itself is not undesirable. Another is that engineering professors often lean unduly towards academic views and processes, and thus lose touch with the spirit of the engineering world. Greater than either of these is the tendency of all things to move in the line of least resistance, and all learning which depends upon the intellect alone is more easily acquired than that which depends upon other sources. The proof of this need go no further than to remember that no literature is finer than that written two thousand years ago; no philosophy has fundamentally improved upon that of the ancients; the highest flights of intellect and mathematics were reached during the ages in which the world was observed to be composed of four elements—earth, air, fire and water.

---

*An address delivered to the graduating class of Stevens Institute of Technology on Thursday, June 16, 1904.

A review of knowledge shows the great preponderance of the intellectual over the material, and it is only within late centuries, in fact almost the past century, that the human mind has seemed capable of turning from the lesser resistance of intellectual attainment to the greater capacity for physical observation and comprehension. We have but recently come to the era of intense mental operations, dealing with laws and principles which require insight greater than the intellect can grasp unless aided by the senses. Contrary, therefore, to common belief, I assert that the highest refinement of knowledge follows from the highest use of the senses; and that it has taken thousands of years of pure intellectual development to attain a state in which the powers of nature can, through human intellect, be made useful to mankind, and add largely to knowledge. Do not, therefore, get a wrong view of the faculties involved in science, in the application of the laws of nature, applied mechanics, and the powers of comprehension which underlie engineering. There is still room for doubt—not debatable here—as to what constitutes liberal education.

I hope for the time when the spirit of engineering as found in practice will form a more definite part of engineering education. This, I think, must come through the professor keeping in close practical touch with the engineering world. There are various ways in which this may be accomplished, but I know of none better than by each professor doing a reasonable amount of practical work for commercial purposes. Under some conditions, this may be consistently accomplished during a portion of his time, but I am inclined to think that eventually our professors will devote all their time to instruction while they teach, and go periodically into the world, a few years at a time for practice. Thus the professorial life would not be so exclusively educational, and our growing engineering institutions may be enabled to enlarge their faculties by the devotion to teaching of a portion of the time of men who are primarily engaged in commercial work.

Now that you have your so-called education, what are you going to do with it? I cannot tell you, but I can suggest some points of view.

Begin by forgetting yourself. All thought of self is some form of selfishness, and selfishness never produced anything better than more selfishness. It often breeds something worse. Genius is all right in its way, but it will not do your work. Get a right idea of work. Remember that time is the essence of most things, and is not inconsistent with thoroughness.

We hear much about opportunities. They are everywhere plentiful. Remember that your opportunity is the little one that lies squarely in front of you, not the large one which you hope to find further along. Many a man is surrounded with opportunities who never seizes one. There are traditions that Adam, William Tell and Sir Isaac Newton, each had an affair with an apple, but with different results.

Your first duty is always to that which lies across your path. The only step which you can take in advance is the next one. This leads to a simplicity of action which is commendable. Don't ramble.

The refinement of thought which is apt to follow high training often leads the mind to overlook simplicity and to even seek complexity. The wealth of modern appliances tends likewise, and it is thus easy to acquire that over-refinement often termed theoretical, as against the simplicity which is called practical.

From one point of view, all graduates can be divided into two classes; those who think their knowledge is a little long for their opportunities, and those who think most anything is a little long for their knowledge. Both are apt to think that the knowledge they have acquired will become the essence of performance. You will soon find that knowledge hasn't much to do with effectiveness. It is necessary, only as words are essential to the expression of thought. You will find knowledge a good tool, but not the vital force with which you perform. You will fall back upon human effort and action, and find that it is the human-engine and not the knowledge-engine that does the work.

Cultivate singleness of purpose. This is more important than you may think. It is intuitive with the comparatively ignorant, and often absent in the highly trained. We are frequently surprised at the great competency of the ignorant contractor or foreman, on whom judgment is often passed by saying that he is a practical man and gets results. Analysis will show that his best quality is singleness of purpose, which leads him to vigorously do the one thing before him, without distraction following from knowing or thinking about too many other things.

The broadening power of education and training increases the range of contemplation, but unless the power of concentration is cultivated there follows a tendency to scatter instead of to acquire that singleness of purpose which leads to effective action. David Starr Jordan has said: "The purpose of knowledge is action. But to refuse action is to secure time for the acquisition of more knowledge. It is written in the very structure of the brain that each impression of the senses must bring with it the impulse to act. To resist this impulse is to destroy it. * * * This lack of balance between knowledge and achievement is the main element in a form of ineffectiveness which, with various others, has been uncritically called degeneration." Thus President Jordan shows how even much more than a little knowledge may be a dangerous thing. The highly trained man therefore needs, as a complement to his training, unusual powers of concentration, in order that the virtue of singleness of purpose may not be lost. This faculty a man must have or acquire himself. It is not in the books. It cannot be taught. It can only be suggested by precept and example.

From directness of purpose naturally follows diligence in getting what you go after, and not being easily turned aside by resistance. When you are getting what you go after, get it all. Avoid the mediocrity of compromise. Be thorough and stand for full competency in everything, from main essentials to details. Just so far as education, assisted by concentration, contributes to singleness of purpose it is useful, but where by length, breadth or depth it dilutes human effort, it lacks value. It is, therefore, not so much the question of how much educational training you have as it is how you use it. Some can use a little with great effect, because their point of view is right; others scatter so badly that they cannot use their knowledge at all; while some distorted minds seem to have a faculty for misapplying a large amount of acquired knowledge through complicated processes full of error. To be right, you must be one hundred per cent right. Charity may pardon human nature its percentage of delinquency, but this is a human matter. The laws of nature, mathematics, and engineering, do not pardon anything. The man may therefore be absolved from censure, but his work must stand the rigid test of inviolable law. Nor is it too much to say that you must be right the first time. Much of our engineering is only done once, and it must be done right that once. A man who has learned by experience to do a thing deserves no credit for doing it right. He is then only a repeating machine. Real power is characterized by ability to perform right the first time that which a man never did before. Such performance involves the power to assimilate and adapt experiences, of more or less like or unlike kind, in a way to bring forth correct results. This is the true use of experience, wherein a man is a thinking, active power, and not a mere repeater.

Clearness of thought is an essential often lacking. This, too, follows from concentration and singleness of purpose. Many minds confuse themselves with a wealth of ideas, grading from the well-formed to hazy, indistinct conceptions. You can clear your mind by proper habits of thought. Train yourself to separate essentials and non-essentials and confine your consideration to the essentials; to distinguish between what you know and what you only vaguely surmise, clearly eliminating opinion from facts. Nothing is more helpful than conference with yourself, in which you determine what you think of your own thoughts. This is aided by the moderate cultivation of system—thinking in an orderly manner, beginning at the beginning, ending at the end, and being sure to have a middle. With this there should be no slavery to system, but let each find his own logical way.

Besides what are commonly known as ideas, men have intuitions—sometimes called impressions or opinions—which they cannot readily prove. These I believe are identical with reason, except that while reason is composed of a sequence of distinct ideas, each capable of expression, intuitions follow from the capacity of the human mind to integrate small ideas and impressions, each of which is too small to stand alone, or to be readily expressed, but which integrated form a concrete mental impression, called an intuition, and which is of exactly the same character as reason, except that it is composed of smaller and almost intangible units. Do not, therefore, discard intuitions as inferior to reason. Analysis will sometimes develop intuition into an expressible logical thought.

You have all had ideas and you will have more of them. Some ideas seem bigger than others. These mental forces, like other forces, only do work when in motion. Hence your ideas are only valuable when put into execution, and this often requires more talent than to originate them. Some men seem to consider their ideas so good that they will execute themselves.

A point of view is involved in the power to rationalize. This gain is a thing which each man does for himself in his own best way, and its essence consists in asking one's self whether the thing is reasonable. It is a great check upon error. It applies equally to nearly everything of which engineering is composed. It is the power of the human mind, after performing in more or less systematic and conventional ways to stand off and look at results and ask one's self whether they are reasonable. One man will figure that certain material weighs two hundred tons, and believe it. Another will say that there is something wrong in that, for it all came on two cars.

Every young man comes sooner or later upon a dilemma, in which he is more or less drawn in opposite directions by his confidence on the one hand and timidity on the other; a desire to perform backed by the courage of his convictions, but on the other hand resisted by his inability to see his way through in orderly progression to a desired end. This is about the time to show your nerve. Don't be dazed and baffled, but make a start. Use your wits and you will get somewhere, and if you cannot always see the end it will constantly get nearer and plainer when you go as far as you can see and then see how far you can go.

Another point of view concerns engineering expression. This may be through designs, drawings, mathematical determinations, or words, and finally by work done. The lamest of these is words. All engineering is so non-literary in character that the use of language is too much neglected, leading to expressions that do not properly convey thought. In engineering, it is not rhetoric but diction that makes expression clear, and diction is best learned from the dictionary. It is well for a young engineer to cultivate his vocabulary, and learn to use words in their right sense. They are then usually understood, even by those who have less knowledge. A word of caution, however, against assuming that a lack of facility of expression can cloak an absence of knowing what you think. Engineering documents, specifications and letters are full of mis-statements due to the careless use of langauge. Conciseness can not be over-estimated. Brevity is desirable, but not at the expense of clearness. Conversely, a certain degree of facility should be acquired in reading the words of others. Some seem incapable of understanding plain language when spoken or written. Any one persistently failing to understand the language of others has limitations needing correction.

One of the worst attributes in engineering, and which is fundamentally born of conceit, tends to fasten error, censure and responsibility on others. There are times when a man needs to stand himself up in front of himself and ask: What is the matter with me? The capacity of any man to admit his own error and frailty of judgment is a measure of strength rather than weakness.

Perhaps no personal attributes are of greater importance in the conduct of the business affairs of an engineering life than good cheer and non-contentiousness. Not only because these are right and agreeable, but because they enable a man to work better, to be better understood, and they add weight to his opinion. There is a certain reasonable optimism of manner which makes a man and his ideas welcome, even though they must of necessity sometimes be critical. To vote aye and believe that things can be done makes a man helpful to others and to enterprises. Discontent is not a sign of progression.

Each of you probably has a preconceived notion of following some line of engineering. Be careful about your self-analysis. The field is large and has room for all of the various types of men, some of whom incline to constructive operations, others toward inventive, some to the contemplative. Again, within all these divisions, some tend toward professional and others trade work. No one can advise what is best for you. This you must find out for yourself. I cannot help, however, a certain predilection in favor of a young man being just an engineer, and not any particular kind of an engineer—not specializing while too young, but developing along versatile lines, ready to turn his hand equally well to any task within his general scope. In this, there is a good deal in the point of view, and the man who believes he can apply himself in one direction about as well as another will come nearer doing it than one who thinks he cannot.

When you start your practical work, you will doubtless try to improve things. This is a legitimate purpose, if not overworked. I am not going to attempt to tell you what needs improvements, but the one improvement that most things need is in the line of sufficiency. You can think this over for yourself and apply it where it fits.

There is another point of view seldom considered. It relates to environment and the power to vary. It is pertinent to engineering.

Man ascended through and exists under the laws of an organic evolution, which occurred almost entirely in early geological ages, under water, within a few miles of shore, under substantially constant temperature, constant pressure, and uniform food supply, and thus in about the simplest possible environment. It was caused, primarily, through the force known as the power to vary, and the reason that evolution spanned the space from the simple cell to the vertebrate animal in so short a time was that this power was not resisted by complex environment. When organism emerged from the water to the more complex environment of the land, and as environment grew constantly more intricate, its resistance retarded evolution and resulted in fixation of species until ordinal evolution practically ceased. It is the complexity of the environment of the world that presses upon you and tries to hold you back from the exercise of your native power to vary. A good environment is certainly less harmfully resistant than a bad one, but remember that environment is not a force. It is not a producer. You are the producer. Whatever be your power to vary, environment will only resist and reduce it.

Therefore, remember that all the good you accomplish is going to come out of yourself. You cannot borrow it and you cannot make it out of that which has been poured into you by education or otherwise. All that you receive is only a certain quantity of knowledge, acquired by education, experience, or other training, which will have a certain influence upon what comes out of yourself as your own. It is the inherent capacity to perform with your own brain which will make you what you become, and not the mere transmission of that which you have acquired. Your knowledge, therefore, is of little avail until you make it inherently a part of yourself through mental assimilation and utilization. The clearer you comprehend these things, the more readily you can make use of them as against the process of mere acquirement with a vague motive that in some way or other what you acquire may be a benefit, or that environment will be the force that makes your talent effective. Some have gone through experience without acquiring it, and many a man who has received an education has not got any because he allowed it to be a thing apart from his personality and it slipped away.

ELECTRIC RAILWAY BRAKING

PART II

By STUART J. FULLER

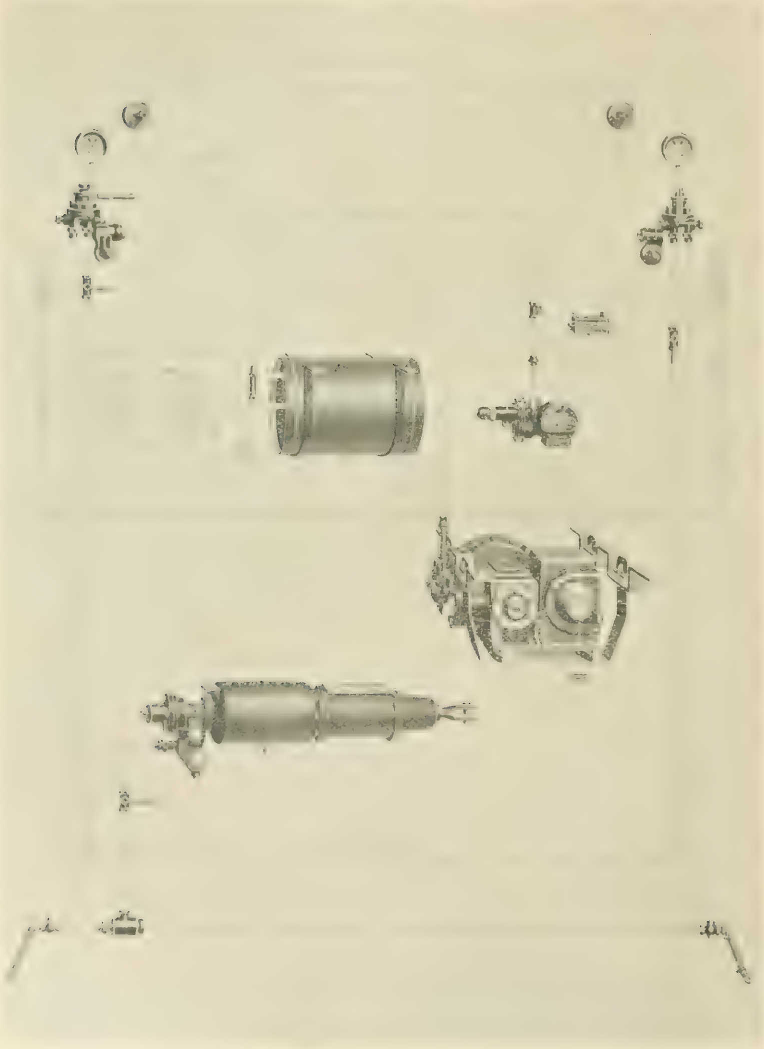
AUTOMATIC AIR BRAKES

THE automatic system of air brakes find its sphere in electric railway service where cars are operated in trains or where electric locomotives are used to haul coaches or freight cars. This type of brake is now used on all of the elevated railways in this country as well as on many surface roads.

The first form of automatic air brake, known technically as the plain or straight automatic, is the invention of George Westinghouse, and was put in service in 1872. The need for an appliance that would simultaneously apply the brakes on all the cars of a long train had made itself felt for many years and numerous schemes had been devised to meet this requirement, including spring brakes, chain brakes and vacuum brakes., None of these have ever been used in electric railway practice with the exception of the vacuum brake, which is quite extensively used on steam railways in England and has been adopted in a modified form by a few electric railways in that country. It is not used for such service in America.

In 1887 the Westinghouse quick action automatic air brake, an improvement and modification of the straight type, was placed on the market and at once established itself unchallenged as the standard of American practice for all classes of railway train service. When electric railways began operating their cars in trains, the quick action automatic air brake was universally adopted. On account of the lower first cost, a few electric roads in this country are still using straight air brakes for train service, but since the development of operating practice to a higher plane this old type, abandoned by the steam roads long ago, is rapidly being scrapped.

In a typical automatic brake equipment the air compressor is motor driven, and is usually suspended under a car, or placed in the cab of an electric locomotive. The action of this compressor is controlled by an automatic pump governor, the same as that used with straight air brakes of the independent motor compressor type, described in the first article of this series. The compressor circuit is provided with a fuse and snap switches at each cab. The compressed air is stored in a main reservoir, the size of which depends not only on the size of the brake cylinder of the motor car and the auxiliary pneumatic appliances to be supplied, but also on the num-



[illegible] DIAGRAM OF AUTOMATIC AIR BRAKE WITH MOTOR COMPRESSOR FOR DOUBLE-END MOTOR CAR ber of trailers, the brakes of which are to the operated from the motor car supply of compressed air.

Fig. 1 shows a diagram of a typical automatic double end equipment for a motor car, including air whistles and the supplementary devices for operating them in the most approved manner. In this diagram the parts forming the air brake equipment are shown fully shaded. The whistling devices mentioned above together with the pipe and fittings, none of which form part of an equipment in the commercial sense of the term, are shown in flat tint.

Fig. 1 also shows the compressor and governor connections which are the same as with a straight air brake equipment; also the electrical circuit leading from the trolley through the governor to the compressor. The further air connections, however, involve principles differing fundamentally from those of the straight air brake. A safety valve is placed on the pipe that leaves the center of the left hand head of the main reservoir. This precludes the possibility of overcharging the main reservoir or the braking system. At the next tee, the air passes through the pipe line leading to the operating valves and containing the cutout cocks. The operating valve is provided with a detachable handle, which the motorman may remove on leaving the cab. Each cab is also provided with a duplex gauge which is piped so as to indicate both main reservoir and trainpipe pressures.

As will be seen from the diagram, three pipe lines lead from each operating valve. One of these, that just discussed, is known technically as the reservoir pipe and in this the pressure is maintained 90 pounds per square inch. A second one, the short piece shown in the diagram, is the exhaust and opens into the atmosphere. The third leads to a line of pipe known as the train line or train pipe which is made continuous throughout the train by means of rubber hose and air tight couplings between the cars.

One of the most important parts of an automatic air brake is the triple valve. This device is illustrated in Fig. 2, which shows a brake cylinder with triple valve bolted directly to its head and connected by means of piping to a detached auxiliary reservoir. Fig. 1 also shows another arrangement of these three pieces of apparatus by which they are all bolted together, the triple valve having a direct connection to the auxiliary reservoir and being connected to the brake cylinder by means of a tube that passes through the center of the auxiliary. This latter arrangement is the one usually employed on electric cars, although the detached type of reservoir is often employed where the complication of apparatus on the car body will not allow sufficient room for the combined type. On electric locomotives where space is especially limited, the triple valve is generally mounted on a bracket inside the cab and piped to the auxiliary end of the brake cylinder. With the automatic system, every car in the train is equipped with an auxiliary reservoir, a brake cylinder and a triple valve. As will be seen from Fig. 3 the triple valves are all connected to the train pipe. The fitting through which the connection is made is an air strainer, placed there to prevent dirt and grit that may accumulate in the train pipe from entering the triple valve.

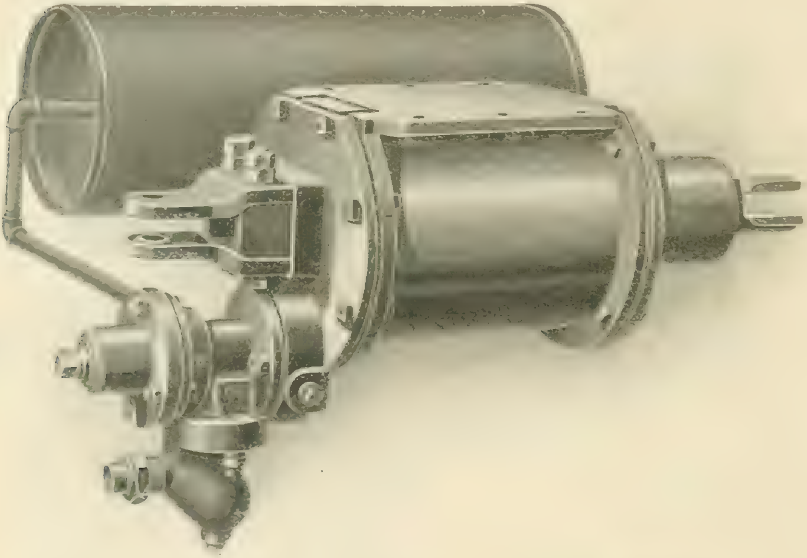


FIG. 2—BRAKE CYLINDER WITH DETACHED TYPE AUXILIARY RESERVOIR

It is this triple valve that makes possible the simultaneous application of the brakes on every car in the train at the will of the motorman. In a general way the triple valve consists of a main piston which constitutes a movable wall separating trainpipe and auxiliary reservoir. Its movement actuates the valves that open and close the various passages through which the air is guided to do its work. The movement of this piston depends upon the difference in the pressures upon either side of it, that is, the difference between trainpipe and auxiliary pressures. When the motorman's brake valve is in such a position that air can flow through it from the main reservoir into the trainpipe, the triple valve pistons automatically assume such a position that the compressed air flows by them into the auxiliary reservoirs until the pressure in these is equal to that in the trainpipe. When this equalization of pressures is accomplished these pistons move to a position of equilibrium and close the connections between the trainpipe and auxiliary reservoirs. If now the motorman's brake valve be placed in a position such that trainpipe air can flow through it to the atmosphere, or if from any cause air be exhausted from the trainpipe, even in comparatively small quantities, the pistons will move toward the trainpipe side, where the pressure has been reduced. By so doing they open passages from the auxiliary reservoirs on each car to their respective brake cylinders, where this air forces the cylinder pistons outward, actuating the system of levers that force the brake shoes against the wheels. Then, when the motorman's brake valve is again placed in the position connecting the main reservoir to the trainpipe the triple valve pistons move back, actuated by the resultant excess of pressure on the trainpipe side, thus again opening communication from the main reservoir through the trainpipe to the auxiliary reservoirs, and at the same time opening passages that allow the air from the brake cylinders to escape to the atmosphere. It is this exhausting from the triple valves at the release of the brakes

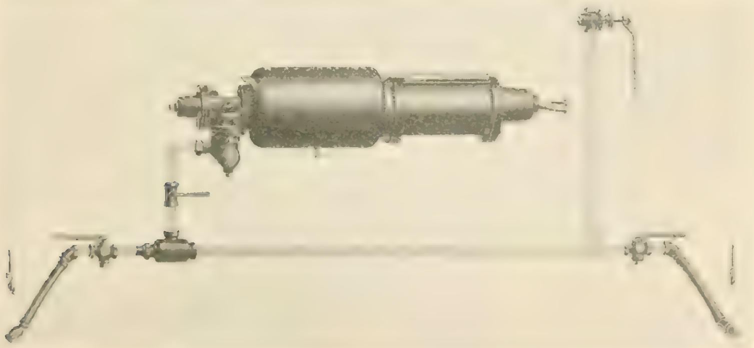


FIG. 3—DIAGRAM OF AUTOMATIC AIR BRAKE FOR TRAILER CAR

that causes the whistling sound heard on cars equipped with automatic air brakes.

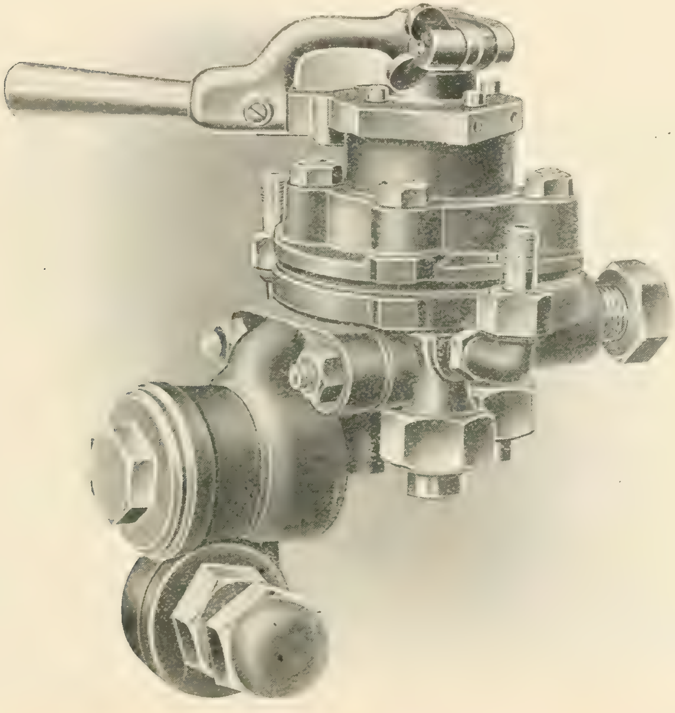
From this it will be seen that the basic difference between straight and automatic air brakes lies in the fact that with the former the air from the *main reservoir* applies the air brakes, while in the latter it is the air from the *small auxiliary reservoirs* that does this work. In other words, straight air brakes are applied by admitting air into the trainpipe—-automatic by exhausting it therefrom.

One of the greatest advantages of the automatic air brake as opposed to the straight air type lies in the increased efficiency and the smoothness of application throughout the train. In the straight air brake the air must pass from the main reservoir through the operating valve and thence through the trainpipe into the brake cylinders of the cars in the train. When used on a train of three or more cars the frictional resistance opposing the passage of this air through the trainpipe is so great that the operation of the straight air brake is slow. With the quick action automatic system the brakes are applied on every car at practically the same instant, only a very slight reduction in trainpipe pressure being necessary to operate all the triple valves and consequently successive application and successive release, which result in disagreeable jerking and bumping, are avoided.

To secure safety a brake must be such that it can be relied upon to operate properly at any and all times. Safety is the strongest feature of the automatic air brake. Each trailer car, and often each motor car as well, is provided with a conductor's valve, which will exhaust air from the trainpipe when opened and thereby it is possible to apply the brakes from any part of the train in case of an emergency.

The bumping and jerking due to successive applications on cars in a train equipped with straight air carries with it the danger of parting the comparatively light car couplings used in electric railway practice. In case of an accident to the trainpipe or couplings from any cause, if the train is equipped with automatic air brakes, the brake is instantly applied on every car, while with straight air the motorman has no air brake at his command at all and is left to rely on the hand brake.

A first-class automatic brake equipment should include drain cocks for all of the reservoirs so that the water condensing from the air, always more or less charged with moisture, may be prevented from getting into the operating valves, triple valves or governor or obstructing the pipe lines by freezing in cold weather. A safety valve should invariably be provided for the main reservoir, and cut out cocks should be placed in the proper pipe lines so that the governor can be removed if necessary without the loss of air and so that defective triples can be cut out in case of emergency. Snap switches should be provided for each cab.



MOTORMAN'S BRAKE VALVE FOR AUTOMATIC AIR BRAKES

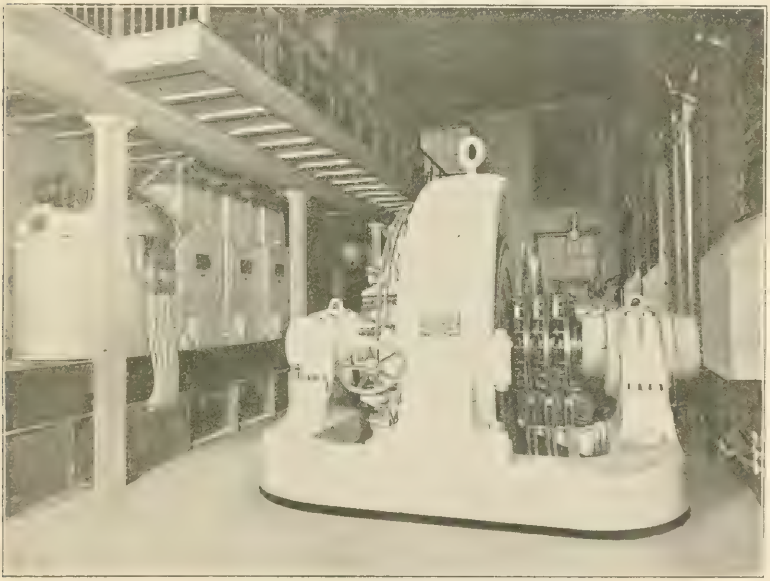
The data needed in order to draw up specifications for an automatic air brake equipment is somewhat more extensive than that required for a straight air brake. The service conditions requiring automatic brakes vary much more widely and the equipment best suited for a given service depends on a number of variable factors which are not present under the conditions where straight air is to be employed. In the first place, whether a motor car or trailer car is under consideration, the size of brake cylinder should be decided. As with the straight air brake this depends on the weight of the car empty but including trucks and motor, i. e., its weight on the rail without live load. The type of auxiliary reservoir, depending on the space available under the car should next be determined. If a motor car is under consideration the size of compressor and of main reservoir are the next consideration. The maximum number of air equipped trailers and the average size of their brake cylinders, together with the size of brake cylinder on the motor car and the air required for air operated auxiliaries must all be considered in deciding on the size of main reservoir. The space available determines whether the main reservoir capacity should be provided by one tank or more, the former arrangement being preferable on account of greater simplicity and lower first cost. The size of compressor is governed by the same factors that determine the size of main reservoirs. It is also necessary to know, in the case of a motor car, whether it is to be operated from one controller only or from either one of two, in the language of the trade whether it is to be a *single-end* or *double-end* equipment. When multiple unit control is used, the main reservoirs are usually connected in multiple by a pipe line through the train, equipped with hose and couplings between the cars, and the pump governors are connected into the system in such a way that the compressors will all cut in simultaneously. If the cars are to be equipped with swing draw bars, flexible joints or hose will have to be provided in addition to the regular trailer hose connections.

The introduction of multiple unit systems of control and consequent increase in the number of electric railways operating trains has opened up a wide field for the automatic air brake. It is probable that the straight air brake will continue to be used for a time on cars that always operate singly, but modern managers will hardly consider it for train service, on cars that are likely to be coupled into pairs or trains.

POLYPHASE INDUCTION REGULATORS

By G. H. GARCELON

IN THE application of alternating currents it is often necessary to regulate the voltage of parts of the transmission circuit. This regulation obviously must be accomplished by some means entirely removed from the generator. The induction regulator is designed for such a purpose.



1000 KW. SIX-PHASE ROTARY CONVERTER AND INDUCTION REGULATOR, IN USE BY THE NEW YORK EDISON COMPANY

The most familiar manner of attaining this remote regulation, as it may be termed, is by the use of a transformer with its primary connected across the line and its secondary, having a number of taps, in series with the line. A device is employed by which more or less of the secondary turns may be cut in, to vary the voltage supplied to the load. Here complications necessarily arise because the circuit must not be broken when changing from one tap to another and the coils between two adjacent taps must not be short-circuited in the process. Here also the regulation is not continuous but in steps of a magnitude which is dependent upon the number of taps from the secondary. Therefore for fine regulation by this method a great number of taps from the secondary is necessary.

An induction regulator is essentially a transformer in which the relative position of the primary and secondary may be varied.

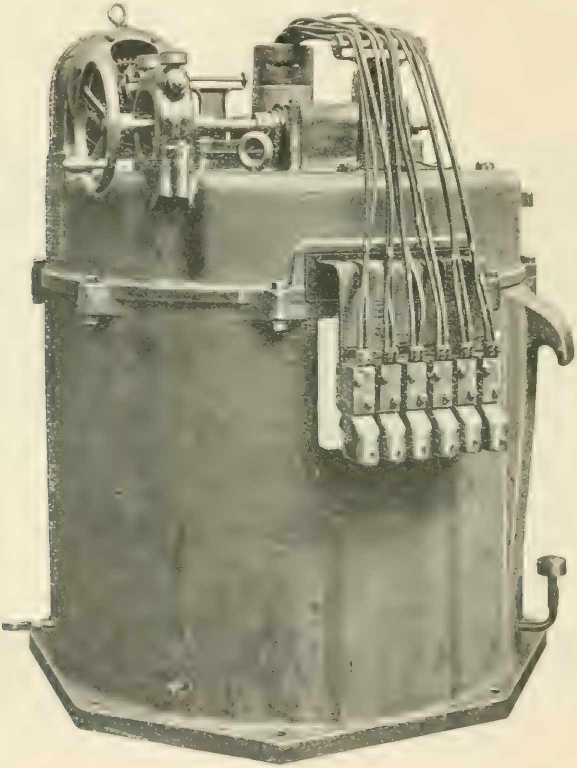


FIG. [illegible]—SIX-PHASE INDUCTION REGULATOR WHICH IN GENERAL APPEARANCE IS SIMILAR TO THE THREE-PHASE TYPE.

Like the regulating transformer, it is connected with the primary across the line and the secondary in series with the line. The regulation of the voltage supplied to the load is effected by moving the primary core which changes the relative position of the primary and secondary coils. This change does not alter the magnitude of the voltage induced in the secondary, but does alter the phase relation of primary and secondary voltages, and therefore changes the value of the load voltage, which is the resultant of the primary and secondary voltages.

Polyphase induction regulators are most commonly used for the voltage control of rotary converters carrying a lighting load, which requires a fine though not necessarily an automatic regulation.

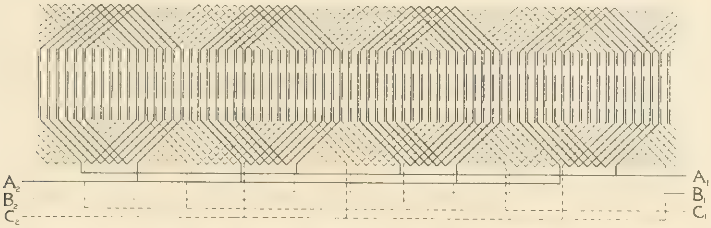


FIG. 2—WINDING DIAGRAM OF THE SECONDARY OF A THREE-PHASE, FOUR-POLE INDUCTION REGULATOR

Fig. 1 shows a complete six-phase induction regulator operated by means of a small induction motor and worm-gear.

The primary core is built up of laminated steel punchings carried on a shaft. The secondary core, also composed of steel punchings, surrounds the primary and is held in a casting which serves as the support of the regulator. Both cores are slotted parallel to the axis of the shaft to receive the coils.

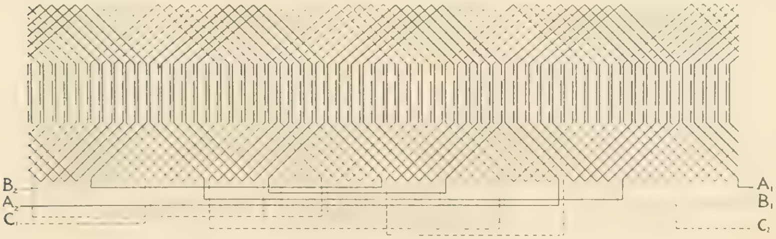


FIG. 3—WINDING DIAGRAM OF THE PRIMARY OF A THREE-PHASE, FOUR-POLE INDUCTION REGULATOR

The secondary is stationary and the primary is arranged with vertical bearings that it may be rotated a portion of a revolution corresponding to one pole. The windings are similar to those of an induction motor having a wound secondary with the exception that the secondary phases are not connected together. Figs. 2 and 3 show the developed windings of a three-phase four-pole induction regulator.

A vertical full line represents one side of a coil which lies in the top of a slot. The adjacent broken line represents one side of another coil which lies in the bottom of the same slot. The secondary winding has a parallel connection because the total load current passes through it. The number of secondary turns in series is determined by the range of regulation desired. Fig 4 shows the station wiring diagram for a three-phase regulator and rotary converter. The upper triangle represents the three phases of the primary of the regulator. The heavy lines parallel to the sides of this triangle represent the phases of the regulator secondary. *S S S* represent electrically operated switches. The lower triangle shows the three phases of the rotary converter.

The current in the primary coils sets up a rotating magnetic field. The load current passing through the secondary coils also sets up a rotating field The primary is so connected that these two fields rotate in the same direction. The voltage induced in the secondary is due to the resultant of these two fields, and its phase position with respect to the line voltage is determined by the phase position of this resultant. The relative position of primary and secondary coils has no influence on the magnitude of the resultant field and therefore the numerical value of the induced secondary voltage is the same at all positions of the primary. Moving the primary core does change the phase position of the resultant field and therefore of the secondary voltage. With no current in the secondary it is easy to see that the resultant magnetic field is a constant because then the secondary field is zero and the primary furnishes the only active field. In this case any change in the relative position of the primary and secondary coils will obviously alter the phase relation between the primary voltage and the induced secondary voltage.

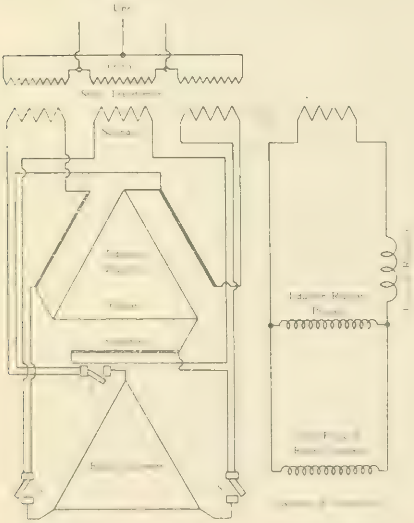


FIG. 4—STATION WIRING DIAGRAM FOR A THREE-PHASE INDUCTION REGULATOR

Now consider the case where there is a current in the secondary. Since both fields rotate at the same speed and in the same direction they may be treated as two stationary fields when considering their phase difference for any given position of the primary coils. Consider the load current a constant and therefore the secondary field constant. In Fig. 5 let OS represent the field set up by the secondary current. The primary field, OP, is in phase with OS and their resultant is OR, the line voltage is OV, the induced secondary voltage is OA, and the resultant or load voltage is OB. This is the position where similar primary and secondary coils lie underneath each other, and the load voltage is a minimum. When the primary is turned the position of its field is obviously changed relative to the secondary field. OP_1 shows the primary field after the primary has been turned through an angle equal to POP_1. In this position the secondary field does not have as much effect on the primary coils, and the current in the primary increases, thereby increasing the primary field and keeping the resultant OR_1 of the same magnitude as before. This action is quite similar to the regulation of a shunt transformer. The induced secondary voltage will be of the same magnitude as before, but being always 90 degrees behind the resultant field it will have the phase relation to the line voltage OV shown by OA_1. In this position OB_1 is the load voltage. When the primary has been turned 180 degrees, its field is opposite the secondary field as shown by OP_2. Here it is more clearly seen that the primary current and field will be increased in magnitude because the primary field is directly opposed by the secondary. The induced secondary voltage is here in phase with the line voltage giving a load voltage OB_2 which is the maximum. Thus it is seen that a movement of the primary through 180 electrical degrees or one pole, changes the load voltage from a minimum to a maximum. If the secondary current does not remain constant the secondary field will change in magni-

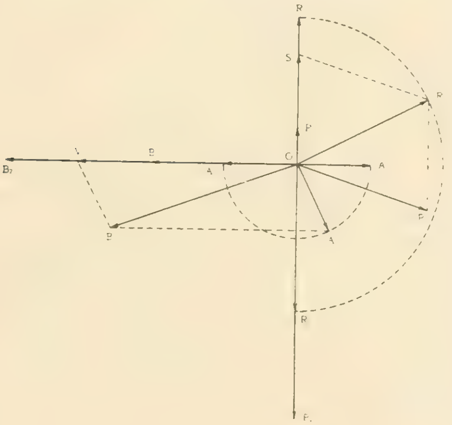


FIG. 5

tude. The primary field will again change to keep the resultant a constant. Of course the resultant field will vary slightly according to the percentage regulation. However, induction regulators are designed to give a very close regulation.

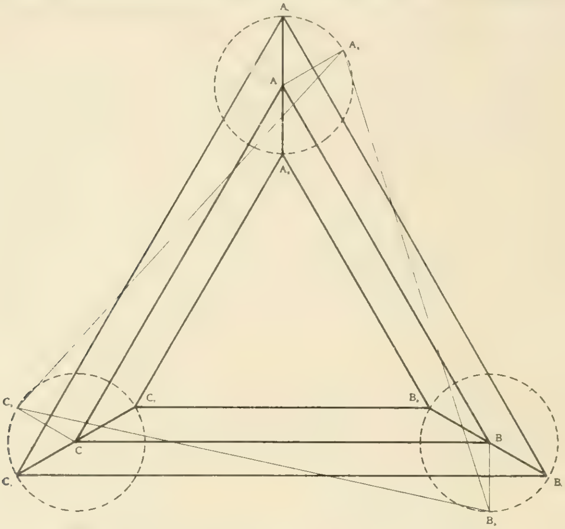


FIG. 6—EFFECT ON THE LOAD VOLTAGE OF THE VARYING PHASE RELATION BETWEEN THE PRIMARY AND THE SECONDARY

Fig. 6 shows the line voltage, secondary voltage and resultant voltage for different positions of the regulator. The trianagle *ABC*

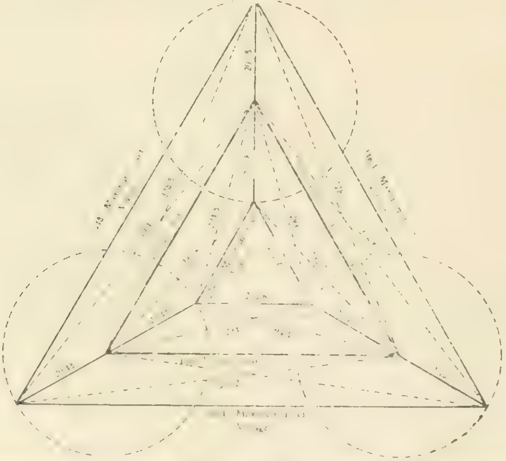


FIG. 7—TEST READINGS TAKEN ON A 50 KW THREE PHASE INDUCTION REGULATOR, TO CHECK THE MAXIMUM AND THE MINIMUM POINTS

represents the line voltages. The secondary voltages are represented by the radii of the circles. With the secondary voltages in the positions AA_1, BB_1, and CC_1, the maximum voltage is given to the load as shown by the triangle $A_1B_1C_1$. When the primary has been turned 180 electrical degrees, the triangle $A_2B_2C_2$ is the resultant, being the minimum. $A_3B_3C_3$ shows the resultant voltage for an intermediate position of the primary.

Fig. 27 shows some test readings which were taken on a 50-kw regulator to check the maximum and minimum voltage points.

The operation of polyphase regulators in parallel, as is done with shunt transformers, is impossible except in such cases where the rotating parts are rigidly coupled. This is obvious from the fact that, if operated in parallel they must have the same phase relations at all times, otherwise local currents will result.

JOHN SEDGWICK PECK

FAREWELL DINNER TO JOHN SEDGWICK PECK

> "There is a history in all men's lives,
> The while observ'd, a man may prophesy
> With a near aim, of the main chance of things
> As yet not come to life, which in their seeds
> And weak beginnings lie intreasured."

JOHN S. PECK, one of the oldest members of the engineering staff of the Westinghouse Electric and Manufacturing Company, severed his relations with the parent company on October 9th, to assume the duties of Acting Chief Electrical Engineer of the British Westinghouse Electric and Manufacturing Company, Limited, and sailed for England within a fortnight after his appointment, where he will take up his residence near Manchester.

Mr. Peck, who for the last ten years has been closely associated with and in a large measure responsible for the development of the Westinghouse transformer, entered the company's employ in 1893, one year after his graduation from Cornell University. He spent a few months in what was known as the Student Course, after which he was transferred to the laboratory. At this time the transformer of larger output than a few kilowatts had not outgrown the bounds of experimentation and all designs were made in the laboratory, where most of the testing was also done. Mr. Peck's work was confined to this class of apparatus, and when in 1895 the electrical engineering department was formed, he was intrusted with the design of transformers and has continued in this work until the present time.

To those who enjoyed an intimate acquaintance with him, the announcement of his election to a post of such importance that he is placed in the first rank of the electrical engineering profession, did not come as a great surprise. The theme of the introductory lines dominated the remarks of most of the speakers at a farewell dinner tendered Mr. Peck shortly before his departure. The dinner was given by his associates in the engineering department, many of whom took that occasion to express, with their estimate of Mr. Peck's decided promotion, the quality of their regard for him and the depth of their regret at his departure.

Mr. C. F. Scott stated that with one exception no other member of the engineering force had been so closely associated with him for so long a time as had Mr. Peck. As Mr. Peck's predecessor he felt there was a common bond between them, both having obtained their primary knowledge of electrical machinery from the transformer and both being inclined to regard, in a way, alternators and motors and even direct-current machines as particular or elaborate types of transformers. Commenting on Mr. Peck's advancement Mr. Scott said: "In one sense the transformer designer has less to do with the system as a whole than the designers of other kind of apparatus. The transformer receives current at one voltage and delivers it at another, the problem of the designer being efficient transformation. As a transformer engineer Mr. Peck might have developed along very narrow lines. Those who know him have observed that he did not devote himself entirely to transformers. He became familiar with the apparatus and the systems of which the transformer is a part. He made a study of the controlling apparatus and of the auxiliary regulating devices which accompany transformers. He became an expert upon the problems of the regulation of rotary converters. He made a study of protective devices and did important work on the development of lightning arresters. Nor did he confine himself solely to electrical matters. When the rest of us were reading our newspapers on the morning train, Mr. Peck would be found with an essay of Huxley or Spencer. He was a contributor to the American Institute of Electrical Engineers and was secretary of the local branch. He was chairman of the lecture committee of The Electric Club. He has in fact made himself an expert in his specific field and at the same time has developed along general engineering lines. He has devoted 95 percent of his energies to his own particular work, while by the efficient use of the remaining five percent he has acquired the qualifications which fit him for his newly assumed position. It is noteworthy at the present time that Mr. Peck has been called to a larger field of activity, not because he is a specialist in one particular line, but because he has general knowledge and sound judgment combined with integrity and earnest purpose."

During the course of the dinner Mr. K. C. Randall, in behalf of the engineers of the transformer division, presented Mr. Peck with a handsome solid silver stirrup cup. The regard in which Mr. Peck was held by the members of the transformer division was alluded to in the remarks of one of the engineers who, in referring to his sense of personal loss, said, "I may safely say that I do have a feeling of sadness. I am not much given to hero worship and perhaps am sometimes lacking in the respect due my seniors, but I assure you I do experience an emotion toward my superior and friend, Mr. Peck, which is akin to hero worship. His keenness of perception, the quality of his sympathy, his evenness of temper, and above all, his never lacking sense of justice and fairness, have endeared him to the hearts of all who have worked under his guidance."

A SLIP INDICATOR

By C. R. DOOLEY

TAKING speed is one of the most deceptive of the operations encountered on the testing floor. Whether the importance of an accurate speed is not appreciated or the human hand and eye not sufficiently trained, the fact still remains that few persons can take speed accurately with the ordinary revolution-counter.

There are two classes of so-called constant speeds: one where the instantaneous speed is practically constant and the other where the instantaneous speed is more or less variable. In the first class, say that of a direct-current shunt motor, the ordinary revolution-counter and watch method will check even more closely than one percent. The second class is found largely in alternating-current machinery where often not merely a single average speed is desired but the relative speed between two machines. Under such conditions the revolution-counter and watch method at best amounts to little more than a fair guess. It is thus evident that a device for more accurately determining speeds of the second class would greatly facilitate factory testing.

A slip indicator is a device for determining the relative speed of an induction motor to that of its driving generator, or more specifically, the mechanical speed of the motor to the electrical speed of its rotating field. Many such devices have been made with different degrees of success. The slip indicator described here was designed by Mr. E. M. Tingley of the engineering department of the Electric Company, though Prof. Seibt of the University of Charlottenburg claims to have used the same principle for measuring slip in 1900.

The induction motor presents perhaps the most difficult condition, as will be more clearly seen from the following:

Take for example a 75-hp, six poles, 25-cycles, induction motor, with low resistance end rings. It will have a slip at full load, of 3½ to 4 percent, or about 20 revolutions per minute. In making a brake test the full-load reading will probably be about the fifth reading taken which means an average difference in slip between sucessive readings of four revolutions or .8 percent of synchronous speed. The flexible electrical connection between motor and generator, the inertia of the rotating part of the motor, the slight variation of the speed of the engine driving the generator, and the varying friction on the brake—all contrive to make the instantaneous motor speed anything but constant, and the average speed for one minute of either motor or generator will easily vary two revolutions or .4 percent. Owing to the flexibility of the system, such variations are seldom in step with each other and thus the maximum error may be .8 percent or four revolutions per minute, which is 100 percent of the slip between two consecutive readings. Unless the difference in slip between consecutive readings during the test is large compared with the probable error in taking the average speed, a satisfactory slip reading cannot be obtained with a revolution-counter and watch. To overcome these difficulties an apparatus is used on the testing floor of the Electric Company the construction and operation of which will be explained in the following:

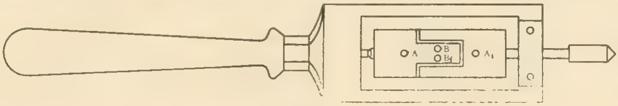


FIG. 1

Construction—Fig. 1 represents the mounted cylinder of a slip indicator for a four-pole motor. Two such pieces as shown in Fig. 2 are made of brass and mounted rigidly on a shaft with suitable hard rubber insulation, the complete cylinder being about two inches long and 9-16 inches in diameter. The shaft is supported in a rectangular frame such that one end extends to engage in the center of the motor shaft. Four small brass brushes about .1 inch in diameter rest radaily on the cylinder at AA_1 and BB_1. The whole is incased with hard rubber which serves to support the brushes and also to protect the cylinder from mechanical injury.

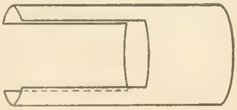


FIG. 2

Connections—Fig. 3 shows a development of the cylinder, which with Fig. 4 readily explains the method of connection. Either AA_1 or BB_1 of the slip indicator is connected across any one phase of the line through a resistance R. The two remaining terminals are connected to a low-reading direct-current ammeter. The cylinder of the slip indicator is made to revolve by holding its shaft firmly in the end of the motor shaft.

The resistance is made necessary by the fact that the line is short-circuited at every reversal of the cylinder. The current in the indicator circuit must then be very small to reduce the sparking at the cylinder to an insignificant amount.

Operation—From Figs. 3 and 4 it is evident that rotation of the cylinder, successively reverses the relative connection of AA_1 and BB_1. Suppose AA_1 connected to the line and excited with alternating current and BB_1 connected to the ammeter which is receiving current at line frequency when the cylinder is at rest. If now the cylinder is rotated such that it reverses the circuit through the ammeter every time the current in the line alternates, the ammeter will receive a continuous current. The magnitude of this continuous current will depend upon the point on the current wave at which the mechanical reversal takes place, i. e., upon the phase relation of the line current and the cylinder. The electrical action is very similar to that of the commutator on a direct-current generator.

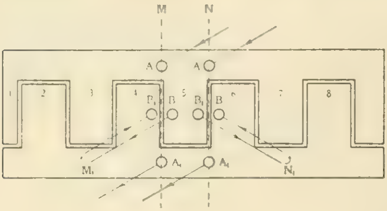


FIG. 3

If the motor in Fig. 4 were replaced by an alternating-current generator, separately excited and running either loaded or without load, the slip indicator would deliver direct-current to the ammeter depending in magnitude (for a given value of the resistance) upon the relative angular position of the cylinder of the slip indicator and the revolving part of the generator.

Consider a two-pole direct-current generator having a single turn on its armature and a two-part commutator as shown in Figs. 5 and 6. In Fig. 5 the brushes are located electrically to commutate in a neutral field. The moment the conductors A and B pass from under one pole to another, their connections with x and y are reversed. The result is a constant current of value L. In Fig. 6 the brushes are located at points of maximum current strength, i. e., at the crest of the wave, and the resulting current is zero, since half of

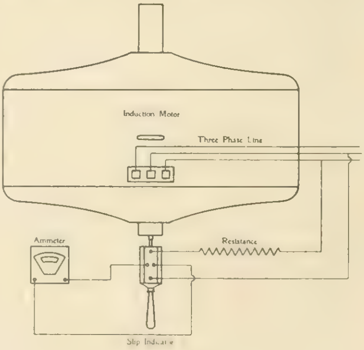


FIG. 4

each wave is negative and half positive with instantaneous reversing at points of maximum value. Wave forms for intermediate positions of the brushes may be easily plotted. Instead of shifting the brush holder the same result may be obtained by changing the angular relation of the commutator to the rotating conductors. Suppose A and B to be connected to the commutator by long flexible leads—the commutator to be free to turn on the shaft and belt driven in the same direction as the armature, but from an independent source of power. If the speeds are exactly the same, the condition of Figs. 5 on 6 or some intermediate one will result. If however, there is a slight difference in speed the current taken from x and y will vary from positive L, through zero to negative L, back to zero, etc. An ammeter connected between x and y will thus read successively, positive, zero, negative, zero and positive, which will represent one complete turn of the commutator with respect to the armature. This is precisely the operation of the slip indicator. Referring to Fig. 4, a local circuit is tapped from the main line which is, say a circuit of 25 cycles. If the commutating cylinder in the indicator has two parts, it will need to run at 1500 r.p.m. in order to obtain the same condition represented in Figs. 5 and 6, i. e., to reverse the ammeter circuit in synchronism with the line alternations. If it has four parts it will need to run at 750 r.p.m. and with six parts at 500 r.p.m., etc. If the indicator has as many parts to its cylinder as the motor has poles its synchronous speed will be the same as the synchronous speed of the motor, i. e., in Fig. 4 if the motor has six poles and the cylinder of the indicator has six parts and if the motor is running in exact synchronism, (no load conditions) the local cir

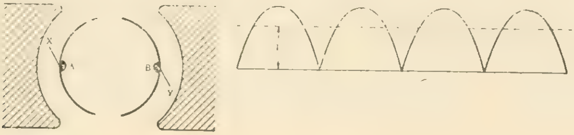


FIG. 5

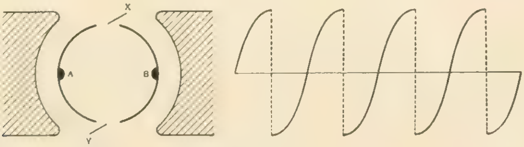


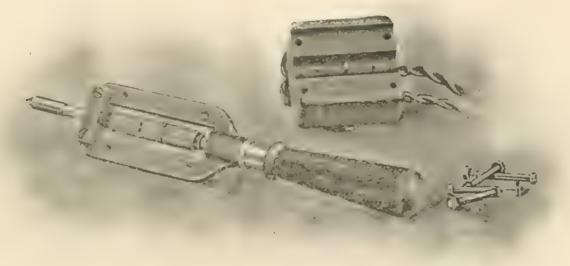
FIG. 6

cuit through the ammeter will be commutated or reversed in exact synchronism with the alternations in the line and the commutator will receive a constant current of a value represented in Figs. 5 or 6 or there between. As a load is put upon the motor its speed drops, the indicator runs slow, the mechanical reversals at the cylinder no longer keep pace with the electrical frequency of the current supply, the electrical position of its brushes is constantly shifting from the crest of the wave to zero and to crest again. Thus in the time the ammeter changes from positive *L* to negative *L* the indicator has slipped one alternation of the line circuit. Counting the vibrations per minute of the ammeter needle gives the slip in alternations of the perophral travel of the commutating cylinder with reference to the line alterations. This, divided by the number of parts on the commutator, gives the corresponding slip in revolutions per minute of the commutator, which is the slip of the motor, since the indicator is held firmly in the motor shaft. In the meantime the average generator speed is taken with a revolution-counter and watch to determine the average frequency of the line, and consequently the synchronous speed of the motor. The motor synchronous speed, minus the slip in revolutions per minute, gives the motor speed.

SLIP INDICATOR IN OPERATION

Recording Device.—It is necessary that the observer have his eyes on the ammeter needle and the second hand of a watch at the same time, which is a little inconvenient. Several schemes have been proposed whereby the ammeter is replaced by a magnetically operated ratchet with suitable dial and pointer. The current in the slip indicator circuit is very small and such a recording device therefore would have to be operated through a relay circuit, and even then its reliability would be doubtful.

While the slip indicator circuit transmits very little power, it may be made to operate a polarized bell, such as used on an ordinary magneto. The strokes can be counted while the observer's eye is on the watch. The range of counting will be doubled by counting complete vibrations. In case a bell is used, remove one gong, and then the count will be divided by one-half the number of poles on the motor. The average person will have some difficulty at first in counting more than 150 per minute, but a little practice in counting by tens or counting every second or every third swing of the ammeter needle will raise the average maximum count to at least 600 alternations, which in the case of a four-pole 60-cycle motor represents a slip of 150 revolutions per minute or nearly 8½ percent. It is, however, possible to determine a slip of 10 percent, which is seldom met with in modern practice. Large slips may be quite closely checked by revolution-counter and watch.



SLIP INDICATOR FOR FOUR-POLE MOTORS

Accuracy.—Within a reasonable variation of frequency the per cent slip will be constant, consequently the slip variation at any given time will be proportional to the variation in the line frequency. The same per cent of error, then, attending the determination of the line frequency (generator speed) will approximately apply to the corresponding slip.

With the revolution-counter and watch method the error applies to the motor speed which is subtracted from the synchronous speed, and the error of this result may be very large, as previously explained. With the slip indicator method the error applies immediately to the per cent slip.

Referring to the previous example of a six-pole, 25-cycle, induction motor, the slip at the first reading on the power curve will be four revolutions, that is 4 × 6 = 24 swings of the ammeter. An error of .8 percent will mean but .19 of a swing which is at once negligible.

The one objection to this slip indicator is its adaptability to motors of but one given number of poles, necessitating a separate and complete device for each style of motor according to its number of poles. The apparatus is, however, of simple and inexpensive construction. There are no delicate adjustments and the wear from every day use during the two years they have been employed in the testing department of the Electric Company has been practically nothing.

THE POLYPHASE INDUCTION MOTOR

PART III

By B. G. LAMME

Speed Variation with Polyphase Motors.

THERE are six methods of varying the speed of polyphase motors, but some of them are applicable only in special cases. These methods are:

(1)—Varying the number of poles.

(2)—Varying the alternations applied.

(3)—Motors in tandem, or series-parallel.

(4)—Secondary run as single-phase.

(5)—Varying the resistance of the secondary.

(6)—Varying the electromotive force of the primary, with constant secondary resistance.

Some of these methods are efficient, while some are very inefficient if the speed is to be varied over a wide range.

Varying the Number of Poles—The first method, varying the number of poles, is efficient to a certain extent, but is limited in the number of combinations of poles obtainable. But if combined with some of the other methods, it may be made fairly effective over a wide range. It consists in varying the arrangement of the primary coils in such a way that the number of resulting poles is varied. This may be accomplished by having two or more separate windings on the primary; or one winding may be used, it being rearranged for different speeds. A secondary of the cage type is the only practical one. With a grouped or polar winding on the secondary, this would need rearranging for the different speeds, just as in the case of the primary. But the cage winding, being short-circuited on itself at all points, is adapted to any number of poles. In general, this method of regulation will allow for only two speeds without great complications, and the ratio of the two speeds is preferably two to one, although three to one may be obtained. The simplest arrangement of winding consists of two separate primary windings; one for one number of poles, and the second for the other. In combination with a variable primary electromotive force, the speed torque curves being of such shape that this method may be used, the variable-pole method of regulation may be made fairly efficient over a wide range of speed. But the two windings considerably increase the size of the motor, while the one-winding arrangements are rather complicated. Consequently, we may consider that this method of speed variation will be used only in special cases.

Varying the Number of Alternations—The second method, variable alternations, is theoretically the ideal method; but it is practically limited to a few special applications, for we have as yet no commercial alternation transformer.

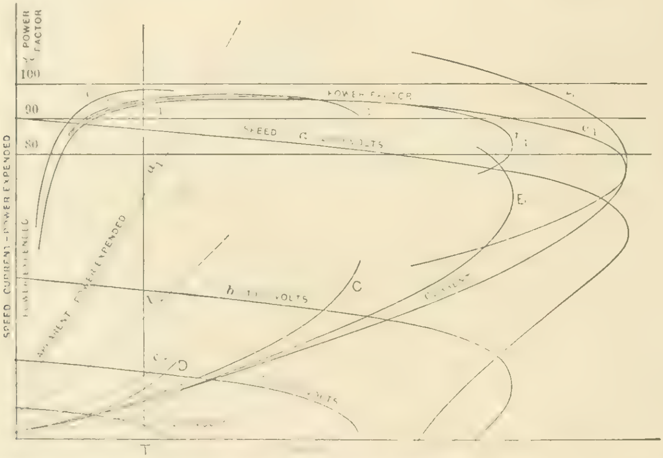


FIG. 18—PERFORMANCE CURVES OF POLYPHASE MOTOR WITH DIFFERENT ALTERNATIONS AND ELECTRO-MOTIVE FORCES

In a few cases, where but one motor is operated, the generator speed may be varied. If the generator is driven by a waterwheel, its speed may be varied over a wide range, and the motor speed will also vary. If the generator field be held at practically constant strength, then the motor speed may be varied from zero to a maximum at constant torque with a practically constant current. This is a convenient method of operating a motor at a distance from the generator. The speed of the mtor may be completely controlled by an attendant at the generating station.

Fig. 18 shows the speed-torque and other curves of a motor when operated at 60, 30, 15 and 6 cycles per second, or at one hundred, fifty, twenty-five and ten percent of the normal alternations. The speed-torque curves corresponding to the above alternations are *a, b, c* and *d*. The current curves are *A, B, C* and *D*. This figure shows that for the rated torque *T*, the current is practically constant for all speeds, but the electromotive force varies with the alternations. Consequently, the apparent power supplied, represented by the product of the current by electromotive force, varies with the speed of the motor, and is practically proportionate to the power developed.

Motors in Tandem or Series-Parallel—The third method is to run motors in tandem or series-parallel. In this arrangement, the secondary of one motor is wound with a grouped or polar winding to give approximately the same electromotive force and number of phases as the primary. This secondary is connected to the primary of a second motor. The secondary of the second motor may be closed on itself, with or without a resistance, or may be connected to the primary of a third motor, etc. The arrangement with two motors is shown in Fig. 19. At start, motor No. 1 receives the full number of alternations on its primary, and its secondary delivers the same number to the primary of motor No. 2. Both motors will start. As motor No. 1 speeds up, its secondary alternations fall. At about one-half speed, its secondary alternations are about one-half its primary, and motor No. 2 receives one-half the alternations of motor No. 1; it also tends to run at half speed. Therefore, if both motors are coupled to the same load, this half speed is a position where the two motors tend to operate together. By connecting both primaries across the line, both motors will be run at full speed. Thus, with two motors, two working speeds may be obtained. This method always requires at least two motors. Its application is limited to a few special cases.

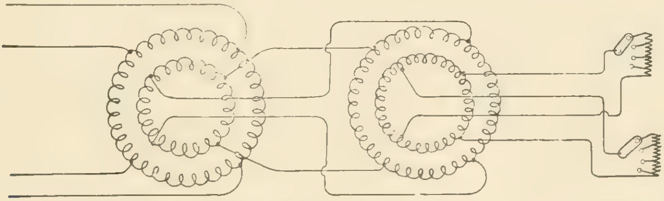


FIG. 19.— DIAGRAMMATIC ARRANGEMENT OF TWO POLYPHASE MOTORS CONNECTED IN TANDEM OR SERIES PARALLEL

Secondary With Only a Single Circuit Closed—The fourth method—the secondary run with a single circuit closed—will give a half speed, and with two or more circuits closed, will give full speed. But the power-factor at the half speed is very low, and the efficiency is not nearly so good as when run at full speed. This may have a few special applications. Fig. 20 shows this arrangement.

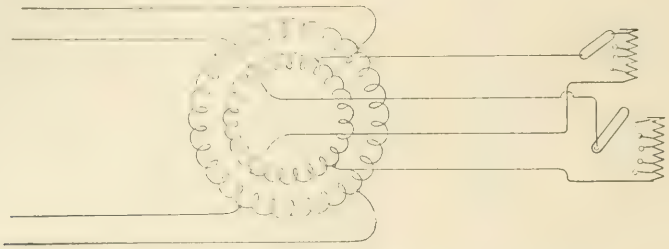


FIG. 20—POLYPHASE MOTOR WITH ONLY ONE SECONDARY CIRCUIT CLOSED

Varying the Resistance of the Secondary—The fifth arrangement is by varying the resistance in the secondary. This method was considered before when the speed-torque characteristics were shown. This will not give constant speed except with constant load, as the speed-torque curve with a relatively large resistance is a falling curve. At heavy torques the motor will run at very low speeds, while with light loads it will run at almost full speed. The speed regulation will be similar to that of a direct-current shunt motor, with a resistance in circuit with the armature. To hold constant speed with variable load, this resistance requires continual adjustment.

Varying Primary Voltage—The sixth method—that in which the primary electromotive force is varied while the secondary resistance is held constant—gives the same results as the fifth method, as the speed-torque curves are similar. To hold a constant low speed, the electromotive force must be varied continually if the load is changing. Like the fifth method, it is not efficient at low speeds, as the reduction in speed is obtained by means of a corresponding loss of energy in the secondary circuits.

For crane work, hoisting, etc., where it is necessary to run at reduced speed for but a portion of the time, either of the methods five or six is satisfactory, but method five requires the use of a variable secondary resistance, and there must be a set of secondary leads carried out to a rheostat if the speed changes are to be gradual. This introduces complication, especially on a crane where several motors are to be controlled. In this case, there must be trolley wires for both the primary and the secondary circuits of each motor. But by method six the control is effected in the primary circuit, and only primary trolley wires are needed, and these may be controlled from one pair of transformers, as explained before. The sixth method is therefore the simplest and most practical one to use for hoisting, etc., and will be found to present many advantages for all classes of work, whether speed regulation is important or not.

METHODS OF VARYING PRIMARY ELECTROMOTIVE FORCE.

There are several methods of varying the electromotive force applied for starting and varying the speed on the Type C motor. These may be classified under three headings:

(1)—Varying the electromotive force from the generator.
(2)—Varying the electromotive force by transformers.
(3)—Varying the motor connections.

Varying Electromotive Force from the Generator—A variable electromotive force may be obtained from the generator in several ways. The generator may be run at low speed, with the field charged. This gives lower electromotive force and lower alternations at the same time. This is adapted only to places where all the motors are to be started at once.

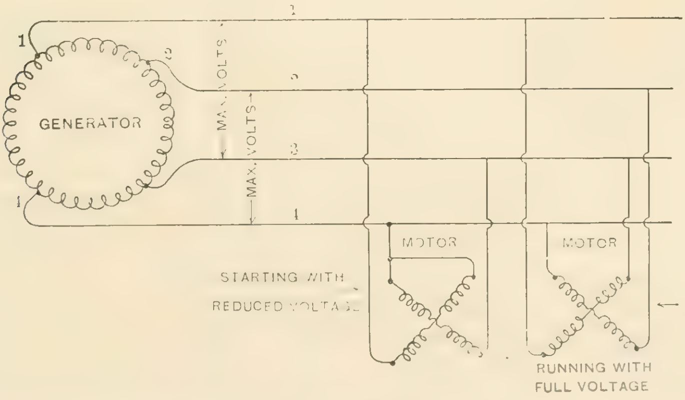


FIG. 21 CONNECTIONS FOR POLYPHASE MOTORS STARTING ON SIDE CIRCUITS

The generator may be run at normal speed and its field charge lowered. This gives the normal alternations with lower electromotive force. This is practicable only where all the motors are to be started at once.

A third method is to so arrange the generator windings that two or more electromotive forces for each phase may be obtained. A lower electromotive force may be used at start, and a higher for running.

The different arrangements of the generator windings for this purpose are as follows:

If the armature has but one winding closed on itself, like a direct current machine, two or three phases may be taken off. For two-phases four leads are used. Fig. 21 illustrates this. Between 1-3 and 2-4 is the maximum electromotive force, and between 1-2, 2-3, 3-4 and 4-1 there is 0.7 the electromotive force of 1-3. The electromotive force 1-2 is at quarter phase to that of 4-1 and 2-3, and the electromotive force 3-4 is at quarter phase to that of 2-3 and 4-1. Therefore, across any two adjacent side circuits we have quarter-phase circuits of 0.7 the electromotive force of the main circuit. A motor thus may be started on any adjacent side circuit and then switched to the main circuit. This method is well adapted for local plants, where the generator electromotive force is 200 or 400 volts. If there are many motors to be started, and the starts are numerous, it is advisable to wire the starting switches so that the various motors are started on different side circuits.

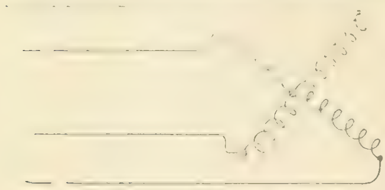


FIG. 22—WINDINGS OF OPEN COIL TYPE, TWO-PHASE GENERATOR CONNECTED AT THE MIDDLE POINT TO ALLOW STARTING OF MOTORS FROM SIDE CIRCUITS.

If the generator winding is of the "open coil" type, a similar arrangement may be obtained for two phases. The two windings may be connected to the middle point, thus giving side circuits of 0.7 electromotive force. This is shown in Fig. 22.

Three-phase connections do not allow any convenient combinations with the generator winding. A fourth wire may be run, however, which will give about 0.58 electromotive force for starting.

Variable Electromotive Force from Transformers—The method of varying the electromotive force by means of transformers, admits of many different combinations. Several of the simpler forms will be given.

(1) The transformers may be so connected that two or more electromotive forces may be obtained.

For two-phase circuits the secondaries may be connected together at the center, as shown in Fig. 23. This gives two main circuits, and four side circuits of lower electromotive force. If an extra wire be carried out from the point 5, then 1-5, 2-5, will form a two-phase combination for 0.5 voltage, while 1-2, 2-3 form a two-phase combination for 0.7 voltage, and 1-3 and 2-4 give full voltage.

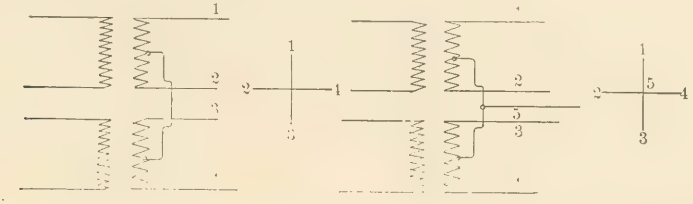


FIG. 23—CONNECTIONS OF TRANSFORMERS ON TWO-PHASE CIRCUITS TO GIVE .7 AND .5 NORMAL VOLTAGE FOR STARTING

Another method is to connect the secondaries at one side of the center, as shown in Fig. 24. Then 3-5 and 4-5 give one electromotive force; 1-5 and 2-5 give a higher electromotive force, and 1-3 and 2-4 give full electromotive force.

These combinations are useful in certain cases, but are not as general in their application as the following method.

(2) Auto-transformers with loops brought out for lower electromotive forces.

In this method, no special combinations of the lines, lowering transformers or generators are made, but, in connection with each motor, a small pair of auto, or one-coil transformers is used for starting. If speed regulation is also desired, as for cranes, the auto-transformers are made larger. From these auto-transformers several loops or connections are brought out. For regulating the speed these are connected to the contact plates or dials of a controller, as shown in Figs. 25 and 26. But for starting purposes only, when but one loop from each transformer is used, a pair of switches are used in connection with the transformers. With the switches open, the motor is disconnected. Throwing one direction starts the motor at reduced voltage and brings it up to almost full speed. The switches are then thrown over to full electromotive force.

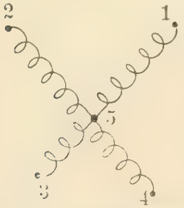


FIG. 24—SECONDARIES INTER-CONNECTED

Two small transformers in a case with one four-jaw, throw-over switch, form what is called an auto-starter. This is readily arranged for either two or three-phase circuits and motors. This makes a most flexible arrangement for starting, as the motor may be put at any location, and the auto-starter may be put in the most convenient position. It also loads all the line wires equally at starting and each motor with its starter really forms a unit separate from all the others. One pair of transformers may be connected to several sets of switches, and thus be used for starting several motors.

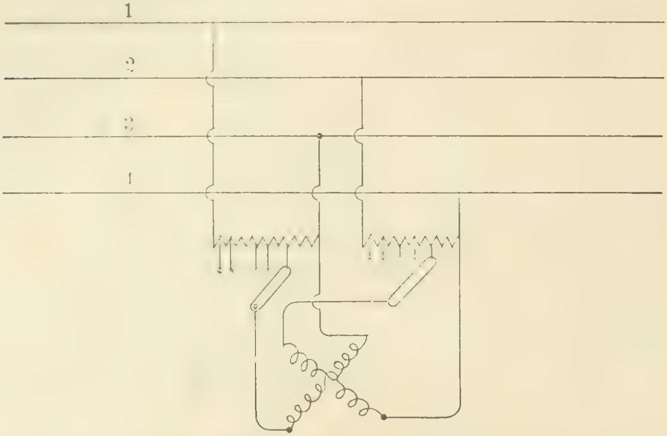


FIG. 25—DIAGRAMMATIC ARRANGEMENT OF AUTO-TRANSFORMERS AND CONTROLLER FOR REGULATING SPEED OF TWO PHASE MOTOR BY VARYING THE VOLTAGE

Where motors are close to reducing transformers, the secondaries of the transformers may have loops brought out, to which one or more switches are connected. The primaries of the transformers may have loops connected to proper switches, and the number of primary turns in the circuit may be varied instead of the secondary. This is applicatble when the transformers supply only one motor, or when several motors are started at the same time. A regulator with secondary movable with respect to the primary may be used. Regulators of this type vary the electromotive forces without any make or break devices, and consequently have no sparking tendency. But they are in general too complicated and costly to compete with the transformer with loops.

Varying the Motor Connections—This is not a method for changing the electromotive force applied; but for varying the number of turns in series with a given electromotive force, and the effect is the same as varying the applied electromotive force. This method is rather limited in its application owing to the complication involved. The simplest case for two-phase motors is a series-parallel combination of the windings of each phase. This is equivalent to using 0.5 electromotive force at start. For three-phase motors, series-parallel may be used, or the winding may be thrown from the star system of connection at start to the delta system for running. This is equivalent to using about 0.6 electromotive force for start. But, as the star connection is preferred for the running condition, this combination is not advisable.

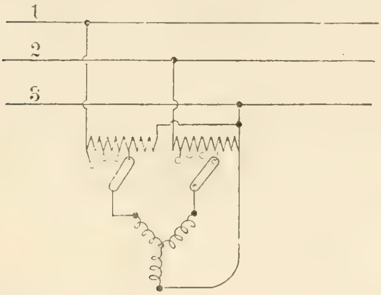


FIG. 26—DIAGRAMMATIC ARRANGEMENT OF AUTO-TRANSFORMERS AND CONTROLLER FOR REGULATING SPEED OF THREE-PHASE MOTOR BY VARYING THE VOLTAGE

Choke Coils or Resistance in the Primary—There is a fourth method of regulation which may be mentioned, but which is not advisable in general practice. This is the use of choke coils or resistance in the primary circuits of the motor, to reduce the electromotive force. These really give varying electromotive forces. With choke coils, the power factor at start is lowered, with correspondingly bad effect on the generator and system. With ohmic resistance in the primary circuit, the reduction of electromotive force is accompanied by a consumption of energy in the primary circuit which in no way represents torque.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

VII—INDUCTION MOTORS

By V. KARAPETOFF

A Series of Lectures delivered before THE ELECTRIC CLUB

[The installment, embodying a general description of the induction motor and its operating characteristics, has been omitted, since this subject is fully treated in a series of articles on The Polyphase Induction Motor concluded in this issue of the JOURNAL.—ED.]

MAGNETIC FLUXES IN AN INDUCTION MOTOR

THE induction motor, like the direct-current series motor, has but one definite set of characteristics. If a certain torque is applied, the motor assumes a definite speed and requires a definite amount of current and energy. This is not the case with a shunt motor, which has the additional variable of field current, so that such a motor may have different speeds for a given torque. Therefore, for the induction motor, like the series motor, there exists but one set of curves giving speed, power-factor, efficiency, in-put and out-put, etc., in functions of the torque. It is thus possible to construct a performance diagram of an induction motor with a locus for each of its electrical and mechanical characteristics, such that to a definite point on one of the loci correspond definite points on all the others; for instance, to each value of primary current corresponds definite values of torque, power-factor, etc.

Addition of Primary and Secondary Flux—In the vector diagrams following, quantities from the primary circuit and from the secondary circuit, are to be added; however, from the very first principles of vector diagrams only quantities of equal frequencies can be immediately added as vectors. The frequency of the secondary flux and current is proportional to the slip, being zero at synchronism and attaining a maximum equal to the frequency of the primary circuit when the speed is zero. Nevertheless the diagram is possible in this case since by means of the revolving rotor the secondary currents and flux react upon the primary as if they were of the same frequency as the primary circuit. Making this assumption the diagram can be constructed by introducing into it, not the real secondary quantities of a variable frequency, but these quantities as they appear in their reaction upon the primary.

The secondary reacts upon the primary through the revolving magnetic flux induced by the secondary current. This magnetic reaction is exactly the same as if the secondary were stationary and currents of the primary frequency flowed in it. This will be more evident from the following: Consider a two-pole induction motor. Let the primary frequency be represented by n_1 cycles per second, which at the same time is the synchronous speed of the motor and the speed of the primary magnetic flux. Let the speed of the rotor at a certain load be n_2, then the difference of the speeds, $n_1 - n_2 = s$, is the slip of the rotor or the frequency at which the secondary conductors are cut by the primary lines of force. s is therefore the frequency of the secondary currents. These produce a secondary flux which revolves, relatively to the rotor, with a speed corresponding to the secondary frequency, that is, the secondary flux rotates about the rotor, and in the same direction as the mechanical rotation of the rotor, with a relative r.p.m. of s. But the rotor itself has a speed of n_2 r.p.m., and thus the absolute speed of the secondary flux is $n_2 + s = n_1$, which is the velocity of the primary revolving flux and the frequency of the primary current. Thus the secondary flux reacts upon the stationary primary as if it were produced by the stationary secondary of a transformer. In this sense the secondary quantities entering into the diagram given below, ought to be clearly understood.

Useful and Leakage Flux—In reality, neither the flux produced by the primary nor that produced by the secondary exists separately. The magnetic flux in the air-gap is a certain resultant produced by the combined action of both primary and secondary. The magnetic fluxes in the primary iron and in the secondary iron are different from the air-gap flux, because they each contain leakage lines.

To construct the performance diagram of an induction motor, we must express graphically the following conditions relating to these magnetic fluxes; (a), The counter e.m.f. induced in the primary winding by the revolving flux in the air-gap, is such that it leaves a part of the impressed e.m.f. just sufficient to overcome the primary ohmic resistance and self-induction. (b), That the e.m.f. induced in the secondary winding by the flux in the air-gap has a value necessary to drive the secondary current through the ohmic and inductive resistances of the secondary winding.

Fig. 50 illustrates the different flux paths both useful and leakage as follows: F_1 is the useful flux produced by the primary winding. It passes through the air-gap and interlinks with the secondary iron. L_1 is the leakage flux produced by the primary current. It simply surrounds the teeth of the primary core. Similarly, F_2 is the useful secondary flux passing through the air-gap and L_2 is the leakage secondary flux surrounding the teeth of the rotor. The arrows of the secondary fluxes are shown in the opposite direction to those of the primary fluxes because the secondary currents are, in general, opposite to the primary current, as in a transformer. In reality both primary and secondary currents are producing their fluxs simultaneously so that the actual fluxes are equal to the resultants, as follows: Flux in the primary iron equals $F_1+L_1+F_2$. The flux in the air-gap equals F_1+F_2. The flux in the secondary iron equals $F_2+L_2+F_1$.

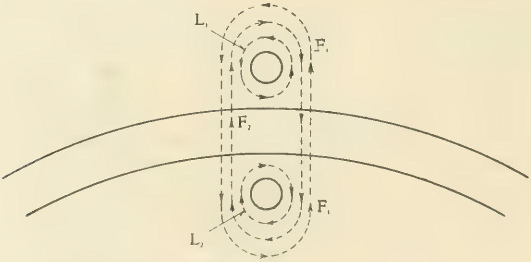


FIG. 50

Since low magnetic densities are used in induction motors, the fluxes may be assumed proportional to the ampere-turns which produce them. The same vectors in the diagram may be taken to represent currents, ampere-turns, or fluxes, by the use of different scales.

Three Parallelograms of Fluxes. Fig. 51 represents the above mentioned relations among different magnetic fluxes or magnetizing ampere-turns. Let $O\ A_1$ be the primary current and $O\ A_2$ the secondary current, the lengths of the vectors being taken so as to represent the relative values of the corresponding ampere-turns of these windings, both reduced to the primary. $O\ A_1$ in Fig. 51 corresponds to the total primary flux, F_1+L_1, in Fig. 50. $O\ B_1$ corresponds to the useful primary flux F_1, and $B_1\ A_1$ corresponds to the primary leakage flux L_1. Similarly, $O\ B_2$ is the useful secondary flux and $A_2\ B_2$ is the secondary leakage flux. The actual magnetic flux existing in the primary iron is then a resultant of $O\ A_1$ and $O\ B_2$, as explained before. This resultant is represented by the vector $O\ C_1$. The actual flux in the secondary iron is $O\ C_2$, the resultant of $O\ A_2$ and $O\ B_1$. The actual flux in the air-gap consists of the useful parts of the fluxes $O\ A_1$ and $O\ A_2$, that is, the resultant of $O\ B_1$ and $O\ B_2$, and is represented by the vector $O\ C_0$. The fluxes $O\ C_1$, $O\ C_2$ and $O\ C_0$ are the only real fluxes in the motor. The fluxes produced separately by the primary and secondary windings do not exist in reality and have been introduced in order to show the origin of these resultant fluxes, and their mutual relations.

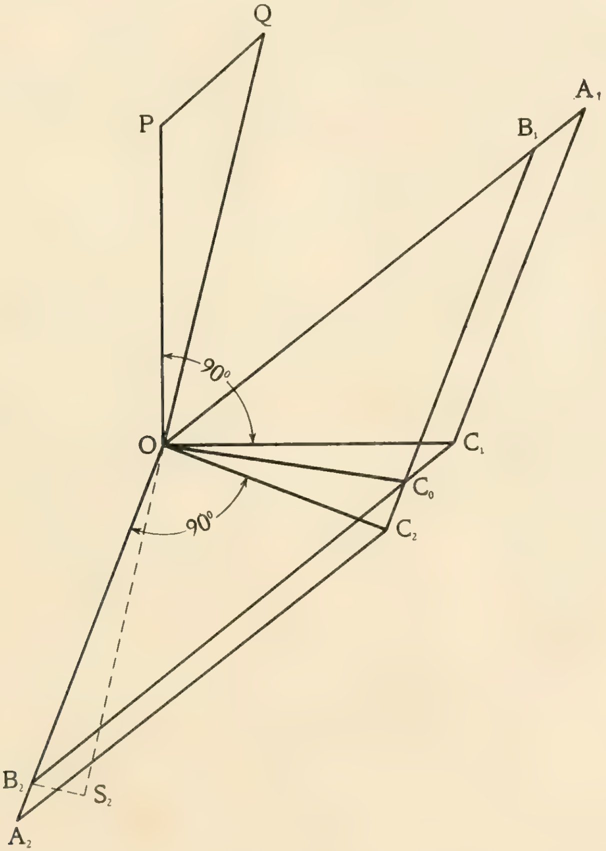


FIG. 51

Primary and Secondary Voltages—$O\ C_1$ is the total magnetic flux which cuts the winding of the primary. The e.m.f. which it induces is then 90 degrees behind it and is represented by the vector $O\ P$. Adding to $O\ P$, the primary ohmic drop $P\ Q$, parallel to the direction of the primary current $O\ A_1$, we get $O\ Q$ equal to the impressed voltage of the motor. This is the first of the two conditions mentioned above. The total e.m.f. induced in the secondary by the flux $O\ C_2$ is 90 degrees ahead of that flux, and as it is only used for overcoming the ohmic resistance of the secondary, this drop coincides with the direction of the secondary current $O\ A_2$. The vector $O\ C_2$ must then be perpendicular to $O\ A_2$.

It will be noticed that the primary and secondary leakages are treated in this diagram in a different manner from that used in previous diagrams of transformers, transmission lines, etc. Here-to-fore the leakage has been considered as an additional e.m.f. at 90 degrees to the direction of the current. In the present case, the leakage is treated as an additional magnetic flux in the direction of the current. It is self-evident that the two ways of treating the subject lead to the same results, since to every magnetizing flux corresponds an e.m.f. at 90 degrees to the vectorial direction of this flux. Previous diagrams have been essentially diagrams of e.m.f.'s, therefore it has been more appropriate to treat leakage as an e.m.f. The diagram of an induction motor is based on the additions of the magnetic fluxes, therefore it is more convenient in this case to consider the leakage as an additional magnetic flux.

FACTORY TESTING OF ELECTRICAL MACHINERY—X

By R. E. WORKMAN

ALTERNATING-CURRENT MACHINERY

THERE are three distinct types of alternating-current machinery in general use.

I. Alternating-current synchronous generators and motors.

II. Alternating-current to direct-current rotary converters. Direct-current to alternating-current rotary converters.

III. Induction motors.

As in the case of direct-current machinery, the testing of each of the above classes of alternating-current machinery will be divided into two groups:

Experimental and Commercial. Each of these classes will be considered separately as different methods of testing are employed due to inherent differences in the action of the machines.

I.—ALTERNATING-CURRENT SYNCHRONOUS GENERATORS

Experimental Testing. The tests commonly made are given in Table I of the Introduction, February issue. The order of tests given there is not necessarily that in which the tests are performed, this order being determined by convenience, is as follows:

(a) Tests made with the machine at rest.

(b) Tests made with the machine driven on open circuit by a separate driving motor.

(c) Tests made with the machine loaded nearly as possible as in service.

The tests will be described in the order in which they are performed.

Loss Tests. The losses in alternating-current machines as in direct-current machines are of three kinds:

(a) Copper losses,

(b) Iron losses.

(c) Friction losses.

(a) Copper Losses—The copper loss in any winding of the machine may be found by multiplying its resistance by the square of the current flowing. Hence it is sufficient to measure the resistance of the windings with the machines at rest. This is done exactly as described in Part II., p. 98, the resistances measured being those from terminal to terminal of the armature and that of the field winding or windings. This test is made with an iron-loss and saturation test table, usually just before the iron-loss test.

The relation of the resistance of a leg of the armature winding to that from terminal to terminal, and the relation of the current per leg to the external current depend on the scheme of connection used.

In the great majority of cases the polyphase systems dealt with in the testing department are balanced and symmetrical; hence only such cases will be considered. The following relations may be used to find the ohmic drop and the copper loss in the armature of any of the various types of machines in use:

Let i=current in each line.

r=measured resistance from terminal to terminal of armature of machine.

d=ohmic drop from terminal to terminal with current i in the lines.

lc=total copper loss with current i in the lines.

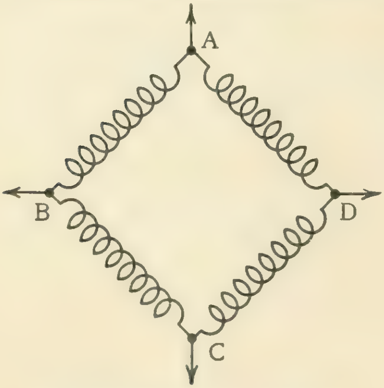


FIG. 51—ARMATURE OF ALTERNATOR, MESH OR RING CONNECTION

I=total current (equal to $2 \times i$ in the case of two-phase circuits and equal to $\sqrt{3} \times i$ in the case of three-phase circuits).

The total current is the current, which, when multiplied by the volts from terminal to terminal gives the apparent power in volt-amperes. It is, in other words, the current in an equivalent single-phase system.

For single-phase machines, $d = i\,r$ and $lc = i^2 r$

For two-phase machines, independent circuits and *Star* connection.

$$d = i\,r$$
$$lc = 2\,i^2\,r$$
$$lc = \tfrac{1}{2}\,I^2\,r$$

Mesh or *Ring* connection. Referring to Fig. 51, it will be seen that the resistance of each section of the winding $=r$

also that $i_{A-B} = i_{B-C} = i_{C-D} = i_{D-A} = \frac{1}{\sqrt{2}}\, i$

and $d_{A-B} = d_{B-C} = d_{C-D} = d_{D-A} = \frac{1}{\sqrt{2}}\, r\, i$

Therefore, since d is the vector sum of the drops from B-A and from A-D, $d = ir$

Copper loss per leg $= \frac{1}{2} i^2 r$

Therefore $lc = 2i^2 r = \frac{1}{2} I^2 r$

For three-phase machines—

Star or *y* connection. Referring to Fig. 52, it will be seen that $r_{A-O} = r_{B-O} = r_{C-O} = \frac{1}{2}\, r$

Therefore $d_{A-O} = d_{B-O} = d_{C-O} = \frac{1}{2}\, i\, r$

Since these three drops differ in phase by 120 degrees,

$$d = \frac{\sqrt{3}}{2}\, i\, r$$

Since the loss in each leg $= \frac{1}{2} i^2 r$

$lc = \frac{3}{2}\, i^2\, r = \frac{1}{2}\, I^2\, r$

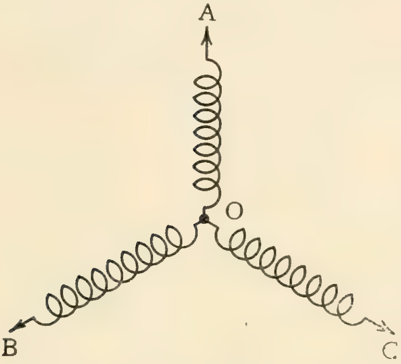


FIG. 52—ARMATURE OF ALTERNATOR, STAR OR Y CONNECTION

Delta or *Mesh* connection. Referring to Fig. 53, it will be seen that the resistance of each section

$$= \frac{3}{2}\, r$$

(This is evident if it is noted that r is the resistance of one section with two others in parallel.)

Since the current in the external circuit differs in phase by 120 degrees from the current in a leg,

the latter $= \frac{1}{\sqrt{3}}\, i$

hence, $d = \frac{1}{\sqrt{3}}\, i \times \frac{3}{2}\, r = \frac{\sqrt{3}}{2}\, i\, r$

Also the copper loss per section $= \frac{1}{3}\, i^2 \times \frac{3}{2}\, r = \frac{1}{2}\, i^2\, r$

Hence the total copper loss $= \frac{3}{2} \times \frac{I^2}{3}\, r = \frac{1}{2}\, I^2\, r$

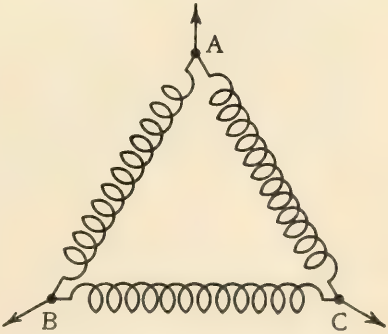


FIG. 53—ARMATURE OF ALTERNATOR, MESH OR DELTA CONNECTION

From the foregoing it will be seen that, as a general principle, the copper loss in a polyphase circuit is one-half the product of the resistance from terminal to terminal and the square of the equivalent current in a single-phase system.

(b) Iron Losses. These are made exactly as in the case of direct-current machines, a description of which is to be found in Part II., p. 102. Fig. 54 shows the iron loss curve for a 1000 kw. 500 volt, 60 cycle, three-phase, 18 pole alternator.

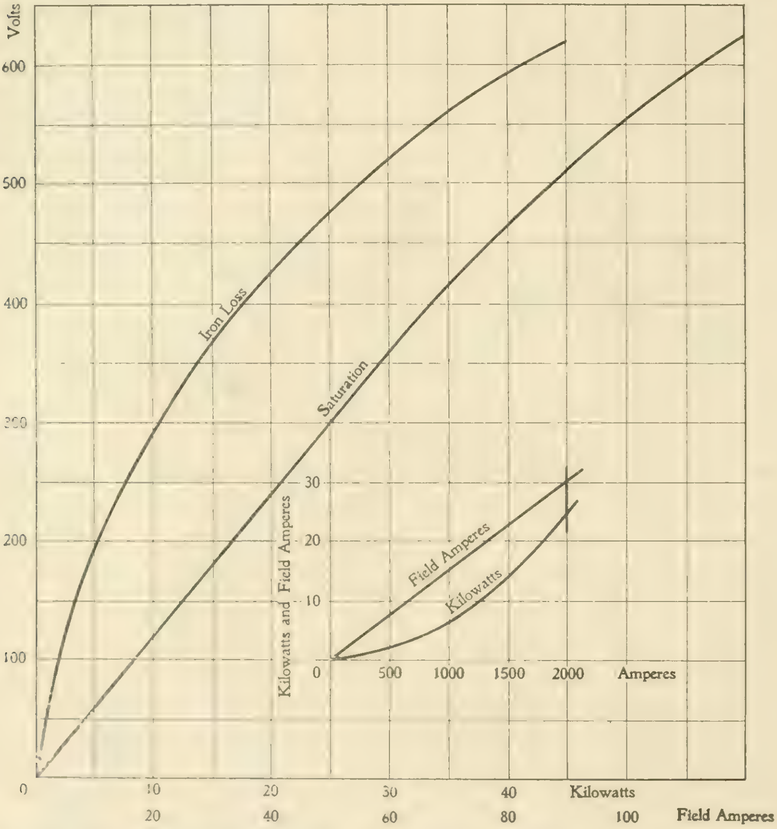


FIG. 54.—IRON LOSS, SATURATION, AND SHORT CIRCUIT CURVES—1000-KW., 500-VOLTS, 60-CYCLES, 3-PHASE, 18-POLE ALTERNATOR.

(c) Friction Losses. The friction losses in an alternating-current generator are only taken into account on belted or two bearing machines. The brush friction-loss is assumed as negligible, and the whole friction loss, in the case of an engine-type machine, is charged to the engine.

Saturation. This test is made exactly as described for a direct-current machine in Part II., p. 103, and Part III., p. 174, and is made for the same purpose. Readings are taken of the voltage on each phase, to see that they are balanced. In the case of a two-phase interconnected machine, readings should be taken across the corners. Fig. 54 shows the saturation curve for the 1000 kw. alternator mentioned above. In comparing this curve with that of the direct-current generator shown in Fig. 15, p. 175, it will be seen that the curve for the alternating-current machine is much straighter. This is because in an alternator, the air gap constitutes a much greater proportion of the reluctance of the magnetic circuit than in a direct-current machine.

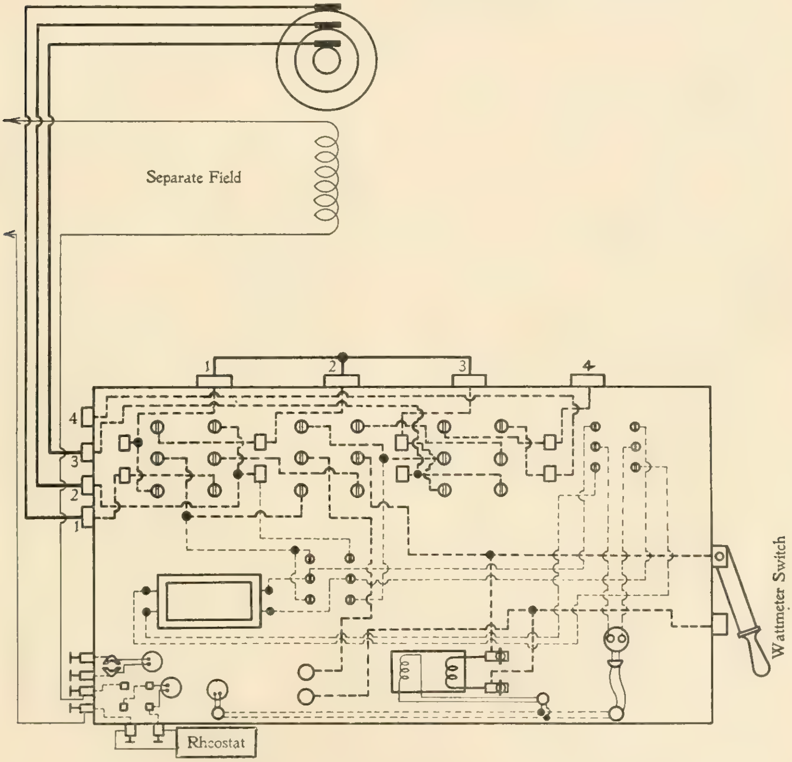


FIG. 55—TESTING TABLE FOR ALTERNATING-CURRENT MACHINES.

GENERATOR SHORT-CIRCUIT TEST.

The object of this test is to obtain an estimate of the effect of armature impedance in reducing the voltage of the machine for a

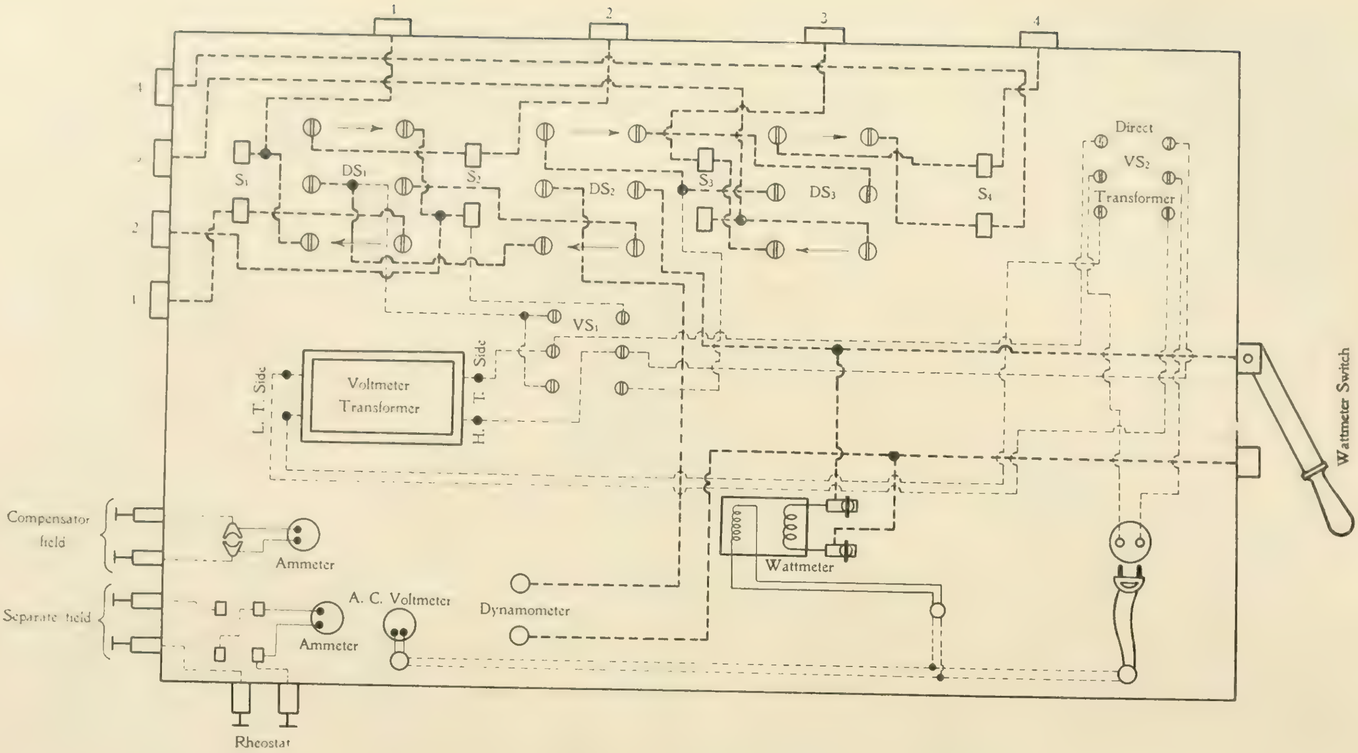


FIG. 56—CONNECTIONS FOR SHORT-CIRCUIT TEST OF AN ALTERNATOR.

constant speed and field current. The use of the results for this purpose will be explained under regulation.

Preparations for Test. The only difference between the short-circuit test and the iron loss, friction and saturation test, is that the generator instead of being on open circuit has the leads from its armature connected, as shown in Fig. 56, to the terminals at the side of the table shown in Fig. 55. The terminals at the front of this table are connected together by means of cables, making it possible to short-circuit the armature by closing the table switches.

In the case of two-phase machines, one phase is connected to terminals 1 and 3. The other phase is connected to terminals 2 and 4. The terminals 1 and 3 and also the terminals 2 and 4, are connected together on the front of the table. In case of three-phase machines, the three leads from the generator armature are connected to terminals 1, 2, and 3, and terminals 1, 2, and 3 on the front of the table are connected together. This arrangement is made so that a dynamometer can be inserted in each of the phases of the generator. A compensated generator has its compensating field disconnected and the secondary of its compensating transformer short-circuited. Measurements are made on this table as described below:

At the front of the table there are three double-pole, double-throw switches $D S_1$, $D S_2$, and $D S_3$. Across $D S_2$ is connected the dynamometer and wattmeter circuit, as shown. The switches S_1, S_2, S_3 and S_4 are in the four phases 1, 2, 3 and 4 respectively. In order to read the current in 1, for instance, it is necessary to throw $D S_1$ and $D S_2$ towards the back of the table and open S_1. To read the current in 2, S_1 must be closed, $D S_1$ thrown over, and S_2 opened. Similarly with the other phases. In order to read the voltages across the phases the double-throw, double-pole switch $V S_1$ is used. The voltage across 1 and 2 is read with $D S_1$ thrown back and $V S_1$ thrown forward. 1 to 3 is read with $D S_1$, $D S_3$ and $V S_1$ thrown back. 2 and 3 is read with $D S_1$ thrown forward and $D S_3$ and $V S_1$ thrown back When $V S_2$ is thrown forward the voltage is measured direct on the voltmeter; when it is thrown back the voltmeter transformer is brought into action, and only a fraction of the line voltage is put across the voltmeter. The watt-meter has its series coil in series with the dynamometer, but this may be short-circuited by means of the switch $W S$, and the wattmeter taken out if desired. The shunt coil of the wattmeter is connected in parallel with the voltmeter, as shown. For the compensating field of the generator there is a dynamometer and short-circuited plug. For the separate field there is a switch, an ammeter and an ammeter short-circuiting switch, as shown.

Conduct of Test. The motor belted to the alternator to be tested, is started up, the speed adjusted and a reading taken, as in the iron loss test, of the motor input with no field current on the generator. The short-circuiting switches on the alternating-current table are then closed, short-circuiting the armature through the table. The generator separate field circuit is now closed, with sufficient resistance in series to give a very low field current and then this field current is increased till half-load current is read on the dynamometer in the generator main circuit, when readings are taken of the driving motor input and the generator separate field current. The same readings are taken with the current at its full-load value.

Working up Results. The iron and copper loss for each of the readings is found by subtracting the motor input with no field current on the generator from the motor input in each of the other cases. The loss thus obtained and the field currents are plotted to the main amperes. Fig. 54 shows the short-circuited curves for the 1000 kw. alternator mentioned above.

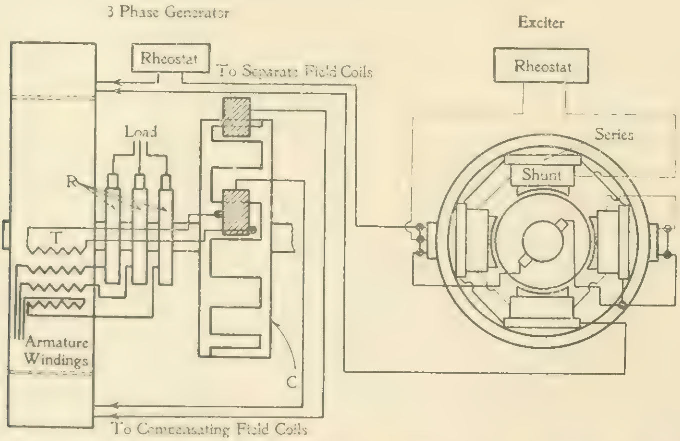


FIG. 57—DIAGRAMATIC SKETCH OF THE FIELD CIRCUITS OF A THREE PHASE REVOLVING ARMATURE, COMPENSATED, ALTERNATOR

THE COMPENSATING FIELD CIRCUIT OF AN ALTERNATOR.

Fig. 57 is a diagramatic sketch of the field circuits of a three-phase revolving armature, compensated alternator. *T* is a series transformer whose primary is in three parts. Each of these parts is in series with a tap from the armature winding to the slip rings *R*. The secondary of the transformer has its two ends connected to the halves of the rectifying commutator *C*. This commutator consists of two copper rings with interlocking teeth insulated from one another as shown in the figure. There is one tooth in each ring for every pair of poles in the field. The spacing of the brushes on this commutator is made such that they rest on teeth connected to different ends of the transformer secondary winding. The action of the commutator is simply to reverse the connections to the transformer twice in each cycle. If the brushes are so placed that the current is zero when the reversal takes place, the current will obviously be always in the same direction, but varying in intensity from zero to a maximum. The brushes are connected to the ends of an auxiliary winding on the generator field. It is evident that as the phase of the armature current changes, the position of the brushes for sparkless operation and complete rectification will also change, and that the compensating effect may thus be varied by setting the brushes at special positions. In order to maintain mechanical balance the compensating transformer is always divided into two parts placed on opposite sides of the shaft and connected in series.

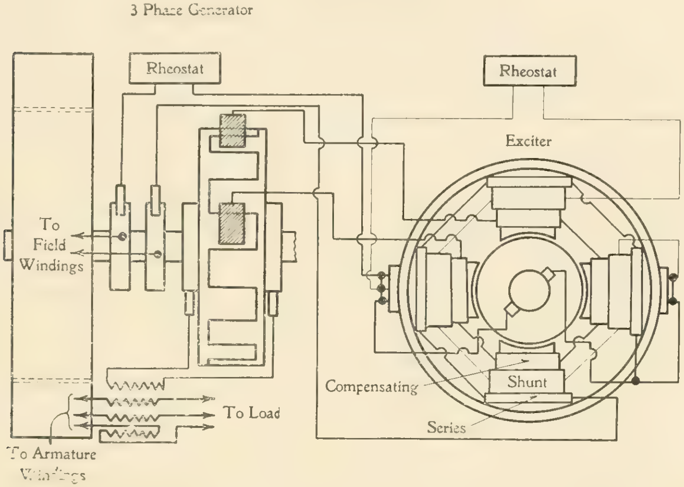


FIG. 58—DIAGRAMATIC SKETCH OF COMPENSATOR CONNECTIONS USING STATIONARY TRANSFORMERS; THE COMPOUNDING BEING EFFECTED ON THE EXCITER INSTEAD OF THE GENERATOR

Fig. 58 shows an alternative method, using stationary transformer and compensating by means of compounding turns on the exciter instead of on the generator. For proper working of this method, the exciter must be worked at a low magnetic density. The diagram is self-explanatory.

Compensator Short-Circuit Reading. This test is made to find the ratio of the current in the compensator secondary to that in the primary. The reading is taken after the armature short-circuit readings, by short-circuiting the compensator brushes through a dynamometer. The compensator brushes are set to give maximum current for each reading. The alternator is run short-circuited with a weak field and the currents in the armature circuit and in the compensator circuit are measured. This gives the ratio required.

REGULATION AND EFFICIENCY. Regulation in an alternating-current generator is the rise in terminal voltage that takes place when full-load is thrown off. This rise is expressed as a percentage of the full-load voltage, the speed being supposed constant throughout. This test may be made under the following conditions, depending on the type of generator being tested:

(1) *Separately Excited Generator.* Speed and field current held constant throughout test.

(2) *Compensated Generator.* Speed held constant.

(a) Constant potential. Separate field set for full voltage at no load and compensator brushes moved at each reading to get constant potential.

(b) Maximum compounding. Separate field set as before. Compensator brushes set so as to give maximum compounding at full-load and held in this position throughout test.

The drop in voltage depends on:

(1) The armature resistance.

(2) The armature reactance.

(3) The demagnetization of the field by the armature, current especially at low power-factors.

The combined effect of (1), (2) and (3) is called the synchronous impedance.

Large machines are generally separately excited, while small ones are more often compensated.

While with direct-current machines it is a simple matter to determine the regulation, with alternators, there are many difficulties due to the following causes:

(1) Alternators are generally built for very high voltages, chiefly owing to the ease with which any desired voltage may be obtained by using transformers. Tests on resistance load at these high voltages are troublesome and it is generally difficult to obtain transformers suitable for obtaining a workable voltage.

(2) Large alternators cannot be easily loaded back as can be done with large direct-current generators.

If however, a regulation point is known, at any known power-factor, it is possible to find, very nearly, its equivalent for the same current at any other power-factor. Hence, tests for regulation may often be made by loading the alternator on resistances, reactance coils, large induction motors or large synchronous motors running on no-load. The low power-factor at which these tests may be made allows the generator to be driven with the expenditure of a very small amount of energy.

SHOP EXPERIENCE

ITEMS FROM THE NOTE BOOK OF THE APPRENTICE

Turbo Generator Field Construction

THE peripheral speed of the rotating element of turbo generators is two to two and a half miles per minute for the large sizes and considerably greater for the small machines. The problem of mechanical construction has therefore been given very careful consideration.

The core is usually made from one piece of solid steel, though for the larger sizes two pieces are used, being pressed side by side on the shaft in a similar manner as in the case of a single-piece core.

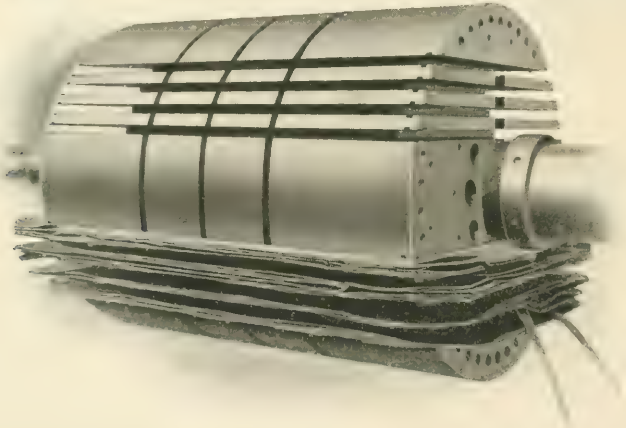


Fig. 1—Two Pole, Rotating Field Turbine Generator One-half Field Wound

The poles are formed by milling parallel slots around the assumed pole direction as seen from Fig. 1. The field windings are placed in these slots—each slot holding one coil of copper strap. These coils are very conveniently wound in the shop by clamping the rotating part horizontally over the center of the table of a boring mill. The copper straps are pulled through tension blocks as the mill table is rotated. Ribbons of insulating material are wound in with the copper straps. After a coil has been wound, the slot is closed on all four sides with brass wedges dovetailed into the outer edges of the slot walls. The finished field of the two-pole type is a perfectly smooth cylinder as shown in Fig. 2. Fields of more than two poles are milled as shown in Fig. 3. In all cases the field coils are secured by heavy brass wedges in the slots. Ventilating ducts are slotted or milled at right angles to the shaft..

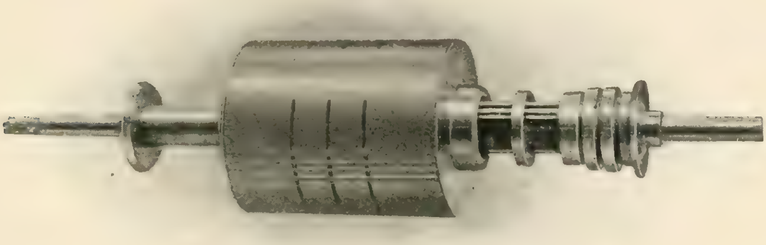


FIG. 2—ROTATING FIELD 400 KW. TURBINE GENERATOR

Each coil is provided with suitable terminals at one end of the field whereby all the coils are finally connected in series and a pair of terminal leads are brought along the shaft to suitable collector rings shown in Figs. 2 and 3.

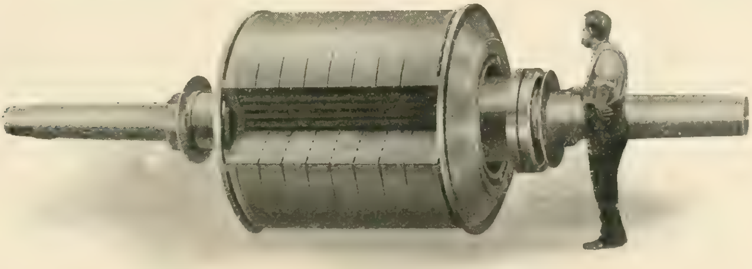
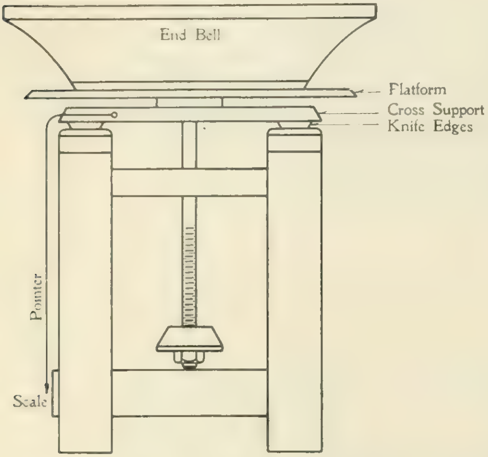


FIG. 3—FOUR POLE, ROTATING FIELD OF 6000 KW. TURBINE GENERATOR

BALANCING TURBO END BELLS

The high speed at which a turbo generator is run requires a very perfect balance of its rotating part. The end bells are usually balanced before assembling, and for this a special modification of the ordinary weighing machine has been devised.

The apparatus consists of a circular platform having a long threaded iron rod secured perpendicularly at its center. Just beneath the platform is a cross arm secured rigidly to the rod. The ends of the cross arm rest upon knife edges. The construction at once has the appearance of a pendulum carrying a circular table top on its upper end.



The lower end of the threaded rod carries a weight with an adjusting nut whereby the center of gravity may be brought very near to the knife edges, thereby effecting a very delicate balance for any given weight of end bell.

The platform is so attached to the rod that it may be rotated and clamped in any desired position. An attached pointer moves over a scale much the same as that of the ordinary chemical balance.

The operation of balancing an end bell consists in carefully centering the bell on the platform and securely clamping it. By adding weights to the light side or boring out on the heavy side the pointer is brought to zero. The platform is now turned 90 degrees and the bell balanced again. This is repeated until the bell is balanced for every position of the platform.

The above apparatus as built for service, is provided with various stops limiting the rotation of the platform and preventing excessive swinging. Means are also provided for relieving the knife edges of the weight of the apparatus when not in use.

EDITORIAL COMMENT

An Apprentice's Impression of The Electric Club Whenever a discussion takes place concerning the training of electrical engineers, and education along electrical lines in general, the terms *theoretical* and *practical* inevitably creep in. To an apprentice in a large electrical manufacturing company the terms have a very familiar sound, for while at college he was constantly reminded that there he was obtaining a theoretical training and that after graduation he must needs have a practical training in order to have rounded out for himself an electrical engineering education. He is more than apt to be filled with the idea that the two elements are separate and more or less independent. Furthermore, he does not yet possess any adequate conception of the significance, either of the terms themselves or of the systems of training which the terms represent.

To the young graduate the Electric Club performs the fundamental function of revealing the significance of what before was vague in his mind, showing how these things which he thought individual elements in his training, are correlated, and that the training which he seeks is neither the one nor the other entire in itself, but one which may be said to be symmetrical and which is justified only by its effectiveness in securing useful results.

It is not intended here to review the already well-known features of The Electric Club. The apprentice comes from college where his efforts have been to answer the questions "Why?" and "How?," to the electric company, where it is rather the questions "How applied?" and "For what purpose?" that engage his attention. The work and observations in the shops afford answers to these questions, complete in some cases, but more often not so. It was probably the realization of this condition that led the founders of The Electric Club to effect its organization. The club exists primarily to meet the needs of its members, and its continuous growth and the development of its individual members from the start have been a measure of the realization of those needs. The opportunities afforded by the *sections* are unquestioned, and the advice and instruction of engineers who are not dealing with theory for its own sake, but who, with theory as a basis, are effecting material results that are useful, cannot but be of great value to the apprentice striving to learn.

At college one is necessarily possessed of a narrow point of view. The association with men at the club whose interests are identical, but whose personalities are different, and who come from widely separated localities, tends to broaden one's view of both men and affairs. The personal contact with the various engineers and other men of experience is a constant inspiration and source of encouragement.

There is no doubt but that all the apprentices who attend the various meetings of The Electric Club, fully appreciate and enjoy the opportunities which are at hand, but there is, however, a failure on their part to realize the *full* significance of their membership. There is a tendency of the apprentices to assume a passive attitude and to merely listen, be advised, encouraged and assisted, rather than to make any reciprocal effort. There should be greater co-operation both among themselves and with those who conduct the work of the club. The Electric Club cannot reach its full effectiveness until all members are filled with an active interest, and with a spirit of co-operation. There must be a feeling among the apprentices that there is a responsibility of having things done by them as well as for them.

The Electric Club is not only a source of engineering information, but it does more in that it creates a state of mind which does not and cannot exist when at college. Here, one being in an engineering atmosphere, begins to see what his knowledge is for and how to use it.

Someone defines life as the correspondence of an organism to its environment. The fullness of one's life regarded as a development in the knowledge and practice of electrical engineering, is measured by the degree of his adaptation to available opportunities. S. S. J. MORGAN.

The Point of View

It is rarely that the lamp of engineering experience shines so luminously as it does in an address which appears in this issue of THE JOURNAL. Mr. Kerr is not speculating, he is not theorizing, nor giving off-hand advice, but he speaks from experience and observation. Hence the weight of what he says. As the active head of Westinghouse, Church, Kerr & Company, he is not only in intimate relation with consulting engineers and construction work on an extended scale, but he directs the work of many engineers and observes the careers of many young men. As a trustee of Cornell University he is in close contact with engineering education and is an advocate of a teaching force of men who spend part of their time in outside engineering service.

The address is dedicated directly to a class of graduates, but it may well be pondered by a student in college and by the young man who is getting new points of view in the school of experience. Older men will read its epigramatic sentences with equal interest and profit.

CHARLES F. SCOTT.

The Road Engineer

The construction man, or road engineer, is required to be familiar with the various types of apparatus made by his company in respect to their construction, installation and operation. As understood in manufacturing organizations, construction work includes all operations performed in the field, or outside and away from the factory. This department is by no means an unimportant branch of the business, nor is it the least attractive to the young engineer. He comes in contact with the customer and the customer's engineers, also with the various classes of operating companies and with the engineers and commercial men of his own company. He is at all time between two firing lines; he must harmonize the interests of the outside concern and those of his own company. To do this successfully calls for the exercise of considerable tact and judgment. And as originality is continually required to solve diplomatic as well as engineering problems, the road engineer necessarily broadens in his views.

A very large proportion of the men occupying responsible positions with the important operating companies have attained their present places through their work in the construction field. In fact when the commercial and other branches of a company are to be recruited the first inquiry often is: *Has he had any outside experience?*

The arrangements of the apprenticeship course lead very naturally to engineering work in the field. In truth it is desirable that a portion of the apprenticeship course include a certain amount of outside engineering work. There seems, however, to be a strong desire among apprentices to get into outside work at the earliest possible moment. This is rather to be regretted, since such men are usually poorly prepared. As a rule they are ignorant of mechanical details and methods to be used in overcoming mechanical and electrical troubles. It is a matter of record that the men who have done the best work are those who have spent the greatest length of time in the factory.

R. L. Wilson.

CLUB NEWS

B. B. Abry, of the Engineering Department of the Electric Company, President of The Electric Club, died October 30, after a very brief illness.

On Thursday evening, October 20, Dr. John A. Brashear lectured before The Electric Club on "Photography as an Aid to Astronomy."

The lecture was illustrated by a large number of slides as unique and fascinating in character as a journey to a neighboring planet. They emphasized the fact that photography has aided science as well in proving old theories as in making new discoveries.

Dr. Brashear, who is always entertaining and enthusiastic, enlivened his lecture by genial reminiscences of Professor Young and of Keeler and Barnard, men with whom he has worked and helped in adding to our world the wonders of a million others.

THE PITTSBURG BRANCH OF THE A. I. E. E.

The Pittsburg branch of the American Institute of Electrical Engineers held its first meeting of the present season at the rooms of The Electric Club on Monday evening, October 17. Three papers selected from those presented at the High Tension Meeting in Chicago, in June, were abstracted and discussed by Messrs. Rowe, Neal and Boggs. The following officers were elected to serve for the ensuing year: Chairman, N. W. Storer; Secretary, S. M. Kintner. Executive Committee, P. M. Lincoln, H. W. Fisher, N. C. McPherson.

TECHNICAL WORK OF THE ELECTRIC CLUB.

A synopsis of the technical work of The Electric Club for the present season has been prepared with two objects in view: First, to enable the members of the Club to select work suited to their individual needs; second, to give to those outside who are interested in The Electric Club a definite idea of the nature of this part of its work.

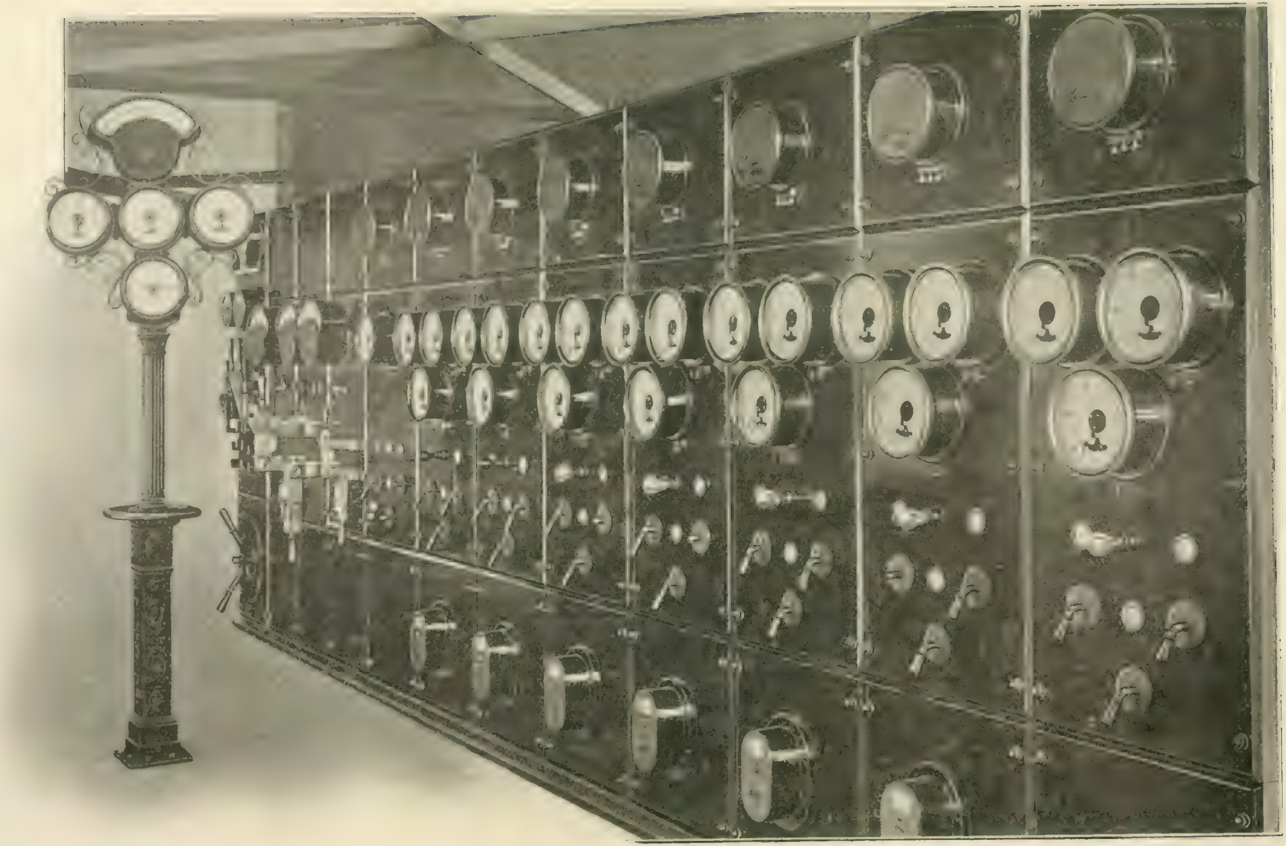
The Technical instruction is divided into classes or sections, each section pursuing a definite line of subjects and meeting periodically for general discussion or special lectures.

The apprentice in the works learns the actual construction of apparatus, but he has no means of learning why the apparatus is constructed as he sees it or how it is used after it leaves the works. The function of the section work is then supplementary to the factory work of the apprentice and must deal with apparatus; with its selection, construction, application, and operation, and under these general heads the schedules have been arranged.

The sections and their leaders are:

Alternating-Current Apparatus	E. L. Wilder
Direct-Current Apparatus	F. C. Hanker
Transformers	J. W. Farley
Switchboards	H. W. Peck
Instruments	P. McGahan
Railway Apparatus	J. E. Webster
Road Engineering	R. L. Wilson
Protective Apparatus	N. J. Neal
Inspection	O. C. Reymann
Insulation	R. D. DeWolf
General Topics	C. P. Machod
Testing	F. E. Wynne

The complete synopsis is printed in a pamphlet of 16 pages and may be had on application to the Secretary of the Club.



SWITCHBOARD GALLERY OF THE PRATT STREET STATION OF THE UNITED RAILWAYS AND ELECTRIC COMPANY OF BALTIMORE

The feeder lines are controlled by oil circuit-breakers electrically operated by small handles on each feeder panel. The station instruments are placed on the post directly in front of the board. Both these features are now embodied in the modern type of switchboard.

THE
ELECTRIC CLUB JOURNAL

VOL. I DECEMBER, 1904 NO. 11

MODERN PRACTICE IN SWITCHBOARD DESIGN

By H. W. PECK

TO the operating engineer a knowledge of switchboard engineering practice is valuable that he may thoroughly understand his particular switchboard, and that he may utilize it to the best advantage in controlling the generation and distribution of power. To the designing engineer this knowledge is indispensable to a full appreciation of the conditions in actual operation under which his design must stand up in competition in respect to its adaptability, reliability, economy and efficiency. To the constructing engineer, it is essential to be familiar with the apparatus that he is to install and the method of and reason for its use, for he it is who must make the actual connections on the board under conditions often quite different from those presupposed at the time of laying out the design. He must first test and operate the system, and finally explain the equipment to the operating engineer. To the superintendent this knowledge is of great aid in judging when and how his board shall be enlarged and improved, or discarded and replaced by a better board. He can see ways in which his system can be improved and adapted to secure a new and a larger business and enter new fields. To the salesman, an intimate and exact knowledge of the switchboard equipment suitable for the requirements of the prospective customer who is in the market for electrical apparatus is of the greatest value in presenting his complete proposition.

The general features of the growth, both mechanical and electrical, of switchboard equipments are well known to every electrical engineer. First there were only switches mounted on the station wall, to which soon were added lead fuses and current and potential indicators, called, by courtesy, meters. The next step was the switchboard, with apparatus mounted on a wooden frame or base as shown in Fig. 1. With the substitution of slate for wood, and marble for slate, and the great improvement in apparatus through the diligent work of skilled designers, we have the modern panel board of the best marble equipped with highly developed switches, enclosed fuses, circuit breakers, and accurate meters for all electrical measurements. Occupying a considerable part of the largest high tension power stations, yet controlled from a small space where the operator has full knowledge of all circuits, is now found the composite controlling, measuring, recording, and protective equipment commonly

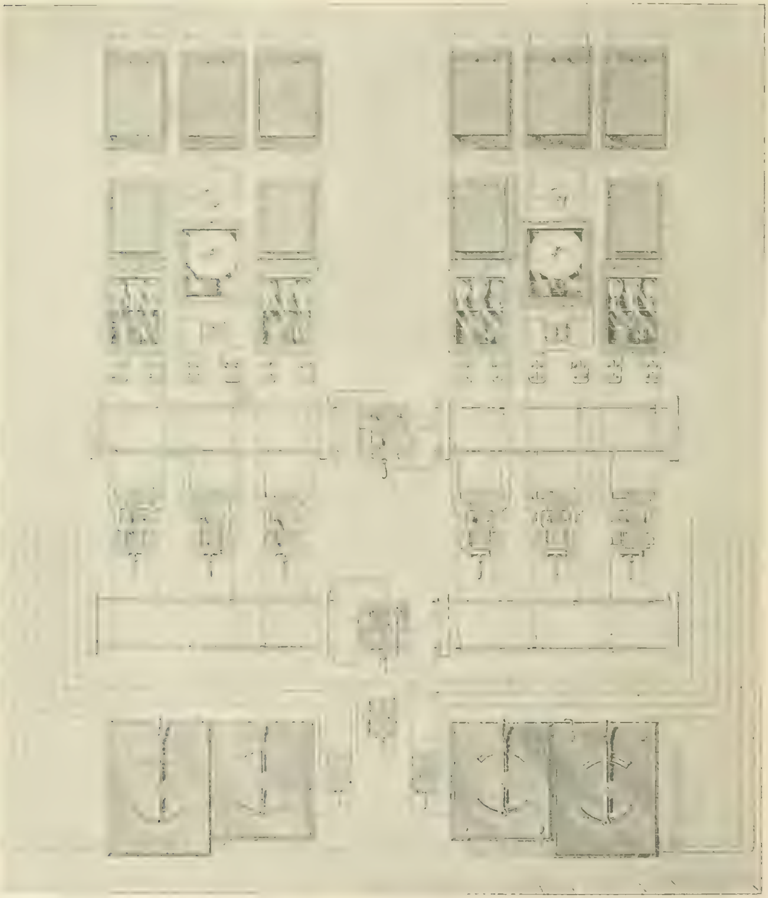


FIG. 1—STANDARD SWITCHBOARD IN 1888, CONTROLLING FOUR FEEDER CIRCUITS. THE CONSTRUCTION WAS ENTIRELY OF WOOD AND GENERALLY FLAT AGAINST THE STATION WALL

called the *distant controlled type of switchboard.* This growth has kept pace with the commercial growth of electrical power from 300 kw, 1000 volt generators and 500 lamp feeders with a type of switchboard as shown in Fig. 1, to 10,000 h. p. 13,000 volt generators and 60,000 h. p., 60,000 volt feeders with a type of switchboard as shown in Fig. 2. This growth has not sufficient interest or value to us as history to be taken up in further detail, but in considering the facts and reasons for modern practice, the important lessons of experience will be brought out.

Few engineers, however, except those who are regularly engaged in this work or have lately undertaken the detail design of a modern power system, are familiar with the methods used by the switchboard engineer to control various kinds of electrical power stations and systems. Some lines of switchboard practice have become quite standardized through wide and intimate experience with systems having practically duplicate operating conditions. In other lines, however, the generating apparatus and the requirements of power distribution are constantly changing and the switchboard engineer must be alert not only to meet all demands but to take the lead and suggest new lines of developments.

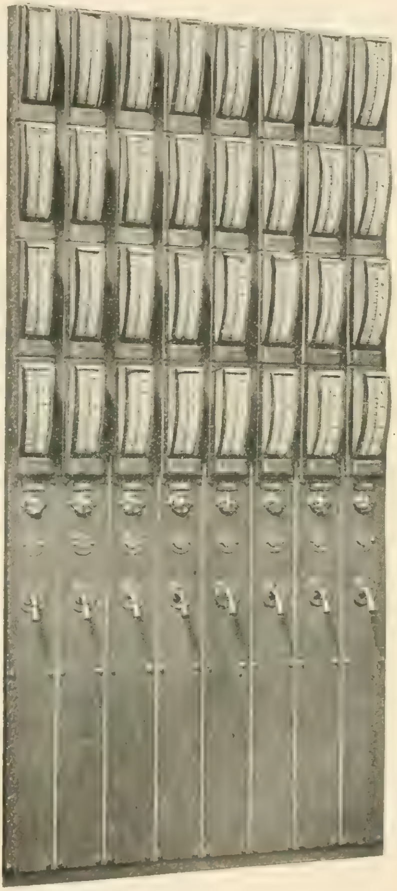


FIG 2—STEEL SWITCHBOARD, VERTICAL EDGEWISE TYPE, CONTROLLING EIGHT HIGH TENSION FEEDER CIRCUITS BY MEANS OF ELECTRICALLY OPERATED OIL CIRCUIT-BREAKERS

It is the purpose of this series of articles to treat of modern practice in switchboard design in such a way as to make them of practical value. The methods of meeting all of the more common requirements will be taken up, the perfection attained by practice in standard lines will be described and explained, and the present tendency in growth will be brought out.

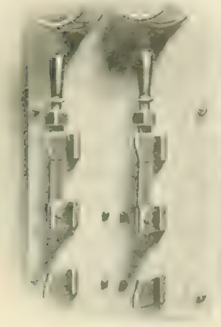
The switchboard is to the electrical power system what the front office is to the manufacturing establishment. It brings together the producer and the consumer. It controls the entire generating station. It receives the output from each generator, and regulates and records the amount of power produced. It conserves the energy available and seeks conditions of maximum efficiency. It gathers all this power together or keeps it safely separate and distributes it to the consumer in the desired quantity and quality to the limit imposed by the generating station or its own organization. It measures and makes record of this power. It adapts the products of the one to the requirements of the other. The machines have a straightforward proposition to meet. They must produce a given amount of power of certain characteristics under specified conditions. Their design is a matter of accurate calculation guided by experience with similar machines, and the result is a fixed quantity. The feeder circuits on the other hand are a variable quantity in number, size, and characteristics. The switchboard is the flexible link between these two. It is the careful assembly of apparatus varying from the massive copper bus-bars or the strong heavy operating mechanism of the oil circuit breakers to mechanism as delicate as that of the finest watch. It must be designed to perform most economically the present duties. The almost certain requirements of the early future must then be provided for, and to make the equipment quite satisfactory the unknown conditions of the more remote future must be considered and an allowance of flexibility made for them. So much for the conditions of operation. But the switchboard must also be protective, to itself, to the generators and to the feeders. It must be designed to reduce all abnormal conditions which may arise in any one part of the system to the normal conditions of the rest, or if this be impossible, to promptly cut off the disaffected part, that the rest may continue normal operation. The greatest strain of an electrical system, that of opening loaded circuits, must be met regularly by the switchboard, and often under the most severe conditions. Insulation and fire risk must be watched most carefully, for the dangers here are the greatest, and yet simplicity is of prime importance for facility and reliability of operation. Every day sees some new apparatus designed or improvements made on the old. With these, the engineer must become familiar, with their electrical and with their mechanical qualities, and be prepared to incorporate them intelligently in the next switchboard design. Some facts regarding materials and apparatus which apply to switchboards in general will best be mentioned before taking up the features of particular practice.

MATERIAL

The materials used for panels are white Italian marble, blue Vermont marble, and slate. They are carefully selected for this purpose and are free from streaks, flaws or conducting veins. The qualities of these materials which have caused them to be universally adopted for switchboard panels, are that they are fireproof, are moderately good insulators, are strong, are easily obtained in any reasonable size, are comparatively inexpensive, are easily worked, and have a pleasing appearance. The Italian marble is of quite uniformly white color and is the hardest and strongest of all marbles. It is very serviceable material and when new or carefully kept presents a very fine appearance in a switchboard, but it shows the dirt very readily, especially oil, which spreads and makes bad stains. The blue Vermont marble varies in shade from one almost as light as the white Italian marble to a quite deep blue. The panels for each board are selected to match in shade and a record of the shade of every board is kept in order that future panels which may be added to the board will match. It takes only about five-eighths of the time to cut or drill this marble as it does for the Italian marble. Ordinary dirt is much less apparent on this marble than on the white marble, but oil stains are a great disfigurement. Slate panels are strong, but are less homogeneous than the marble. Each panel is tested for conducting veins by passing the two poles of a 10,000 volt testing box over the front and rear faces respectively of the panel. Slate panels are always sand rubbed and given an artificial finish, as described below. Soapstone is too soft, weak and

TYPE C CIRCUIT-BREAKERS MOUNTED ON 24 AND 20-INCH PANELS. THREE OF THE BREAKERS SHOWN HAVE A CAPACITY OF 600 AMPERES AND ONE 400 AMPERES difficult to finish well to make good panels, but is much used for other purposes.

The small panels with light apparatus are made of one and one-quarter inch material, the larger ones of two inch material, while panels with very heavy apparatus, especially such as strains its support in opening, are two and one-half inch thick. To improve the appearance of the panels and to prevent the inevitable chipping of the sharp edges, a bevel is cut around the front face, three-eighths inch for panels, one and one-half inches thick, one-half inch for panels two or more inches in thickness. There are standard widths and heights of panels for various types of boards, a large stock of the standard sizes being kept on hand for immediate use.



500 AMPERE, SINGLE POLE, DOUBLE THROW, TYPE D SWITCHES, MOUNTED ON A 24-INCH PANEL.

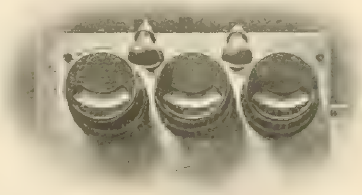
There are three common methods of finishing the surface of the panels. The marble will, of course, take a high polish and retain its natural color. This finish is unquestionably the most handsome when the panels are clean, but is liable to discoloration. Stains can be removed, however, by applying a mixture of plaster of paris, benzine and chloroform. The marble may be given a black enamel finish by painting it with woodman's black, varnishing, baking in an oven at 120 degrees centigrade, rubbing, varnishing, baking and rubbing again, giving a highly polished jet black finish which is very neat and serviceable. This finish does not show the dirt readily and is easily cleaned with soap and water. The third finish is designated as dull black or marine finish. To obtain this the marble is hone finished with emery cloth and black lacquer is sprayed evenly over the surface with an atomizer. This gives a soft appearance which is very pleasing, and the finish is thoroughly practical, being durable, not showing dirt or small scratches and easily refinished if badly scratched or scraped. It can be cleaned like the enamel finish. Slate is always given one of these black finishes.

Marble and slate can be easily worked, a band saw being used for cutting, a chisel for trimming and a sharp pointed drill for drilling, using clear water for lubrication. Large round holes are cut by revolving a steel plate upon the face of the marble and feeding sand and water under the plate.

The frame work for supporting the smaller sizes of panels is made of iron pipe, one pipe being required at either end and between each two panels. Cast iron brackets are bolted to the panel near the top and bottom and clamped with bolts to the pipe. To the bottom of the pipe is screwed a foot-piece, which can be bolted to the floor or to a channel iron base. The frame work for larger panels is made up of angle iron uprights, to which the panels are bolted and which are in turn bolted to a channel iron base and to a flat iron piece across the top. This construction makes a very rigid frame and yet easily handled and readily adaptable, as a panel can be removed from the frame and replaced or changed, or the frame can be removed with the panel if no longer required. The bolt holes in the frame are punched with a jig so that the frame pieces for any particular type of board are strictly interchangeable. Strain insulators are provided, into which are screwed rods for bracing the board from the wall or other part of the building.

Bus-bars and other connections on the rear of the panels, which require a capacity for 300 amperes or more, are made of hard drawn copper strap one-eighth by three inches in section and of a high standard of conductivity. There is also used to some extent copper strap 1/8x1½ inches, 1/8x4½ inches, and ¼x6 inches in section and aluminum strap 0.08x1½ inches and 0.2x3 inches, the latter having the same conductivity as copper strap of the same width. This strap is readily cut, punched, and bent as required, and when several are used in multiple they are spaced for ventilation and heat very little at rated loads. All switchboard parts and connections which carry current are designed for a temperature rise of less than 20 degrees centigrade at their normal rating.

The small wiring at the back of the board consists of No. 10 rubber covered wire. These wires are held in place against the panel and kept at uniform distance from each other at suitable intervals by porcelain cleats. The cross connections between panels are made at the bottom of the board, where the wires are securely taped to-



THREE TYPE K AMMETERS MOUNTED ON A 32-INCH PANEL gether and supported from the iron frame by porcelain clamps. Where the capacity required for the main leads is less than 300 amperes, rubber covered wire of suitable size is used. This is generally stiff enough to be self-supporting between the terminals, but if not, it is supported by suitable porcelain insulators. Round copper rod is often used for moderately high tension alternating current bus-bar, when located immediately behind the switchboard. These bars are insulated with tubes made up of fuller board and mica, and are supported on porcelain line insulators. The apparatus on the face of the board is the *perfection attained by practice,* as the panel designs are changed whenever necessary to adapt them for the use of new or improved apparatus. The apparatus is designed and manufactured to perform its rated functions accurately and safely, to meet successfully the most severe conditions that may be imposed upon it, and to present a handsome appearance. It is usual to leave the current carrying parts of switches, circuit breakers, etc., in their natural color, highly polished. All metal parts of apparatus which are not polished are finished in black japan. The polished metal parts may be nickel or copper plated or given a dull black finish with lacquer. The black finish is the most serviceable and is now most commonly used, being considered the standard.

TWENTY-FOUR-INCH PANELS EQUIPPED WITH 1000 AND 3000 AMPERE TYPE D SWITCHES, TYPE E AMMETERS, AND TYPE E VOLTMETER ON SWINGING BRACKET

INSTRUMENTS

The switches are designated as Type D, and a complete line of them from 25 to 3,000 amperes, single and double throw, one, two, three and four pole, ordinary and quick break, are kept in stock. They are of the single break, unit blade type, simple, strong and liberally rated. For switchboard use they are rear connected, the panel being drilled for the studs and two dowel pins in each jaw block, which prevent the blocks from turning and getting out of alignment. The switches are held in place by means of washers and nuts screwed on the studs and set tightly against the back of the panel. Each switch is tested at its rated capacity after mounting, a maximum of 10 to 12 millivolts drop being allowed between studs. If it is necessary to make the stud of a switch longer than standard, an adapter is used. This is a copper rod of suitable length with right and left hand threads and a brass casting similar to a union, also with right and left hand threads. This is a simple arrangement which insures good contact both between the threaded surfaces and between the end surfaces and can scarcely be loosened accidentally. Standard cast brass terminals and nuts are supplied with each stud unless other sizes or methods of connection are specified.

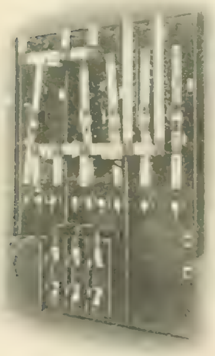
Circuit breakers of two kinds are used, type C and type D. The type C breaker is the well-known brush type, carbon break circuit-breaker, the required capacity being obtained by using a sufficient number of unit sections of the brush. The bottom stud and a part of the iron frame of the breaker form an electro-magnet, which is utilized if desired to open the breaker automatically on overload. This feature can be adjusted for operation at any point between approximately 80 and 150 percent of the rated capacity of the breaker. By means of a coil mounted behind the circuit breaker, it may be arranged to open on no load, no voltage or reverse current. This type of circuit breaker is made in capacity from 200 to 10,000 amperes, single throw, and one, two, three and four pole.

The type D circuit breaker is also designed with brush contact and carbon break, single throw, and one, two, three or four poles. It is made in capacity from 10 to 400 amperes and is opened automatically by means of a series or shunt coil, like the type C breaker, under similar conditions. It is a lighter, more simple and more compact breaker than the type C for similar capacities. It is advisable to keep all circuit breakers closed when not in use to prevent dirt from collecting on the brushes.

Direct current meters are made in four types designated as types D, E, H and K. Type K meters are used on the small boards, the ammeters operating from a series coil of the main circuit within the meter. They are dead beat and have a nearly uniform scale. Types D, E and H are strictly dead beat, have uniform scales, and are guaranteed accurate to within two percent. The ammeters operate from German silver shunts in the main circuit. The voltmeters of capacity greater than 150 volts have resistance in series with their windings. Types D and K are round meters, type E has a long illuminated dial above the round part of the meter, and type H is rectangular with vertical edgewise scale.

Alternating current meters are made in four types, designated as types F, G, I and K. The type K meters are the same as the direct current type K. Types F, G and I correspond to the other direct-current meters, are strictly dead beat and are accurate within two percent. The type G meters have illuminated dials and type I meters are of the vertically edgewise style.

The type F is the well-known long scale meter, the scale extending through an arc of 300 degrees, permitting exceptionally easy and accurate reading. Current coils are connected directly in circuits of five amperes and 400 volts or less, and potential coils are connected directly across circuits of 150 volts or less. In all other cases series and shunt transformers are used. Standard series transformers are designed for a primary current equal to the rated load of the circuit and for a secondary current of five amperes at rated load. Standard shunt transformers are designed for the line potential on the primary and 100 volts on the secondary. Transformers for 10 ampere or for 200 volt secondaries are also occasionally used. Series transformers are built of four types, all being dry insulated. The return type and the through type have primary windings of wire or strap and secondary windings of wire, all leads of the former being at the same end, one primary and one secondary lead being at each end of the latter so that they may be connected in the circuit without making loops in the wiring. The stud type and bus-bar type are designed for capacities of 600 amperes or more with a primary of one turn, which is the straight stud or bus-bar. These transformers have holes of suitable size and shape to slip over the primary, to which they are lightly clamped to prevent turning or slipping. Shunt transformers are made dry type for primary voltages up to 6,000 volts and oil insulated for higher voltages.



REAR VIEW OF PANELS, SHOWING FRAME WORK, COPPER STRAP BUS BARS, ADAPTERS AND TERMINALS

Other alternating current meters are made which correspond in size and appearance to the type F meters. There are four types of synchroscopes using two different principles of operation. This.

FOUR TYPE F AMMETERS MOUNTED ON A 32-INCH PANEL. TYPE F VOLTMETER MOUNTED ON SWINGING BRACKET

however, is not within the scope of the present paper. These may be made with polyphase connections, but preferably are adapted for single phase connections, which are more simple. Types A and B correspond in size and appearance to the type F meters, but types C and D have dials 16 and 36 inches in diameter respectively and have both dials and pointer illuminated with incandescent lamps, so that by day or night they can be readily seen by the engineman as well as by the switchboard operator. Frequency meters when used on circuits exceeding 100 volts are connected to shunt transformers and indicate the effective frequency rather than the actual number of alternations. Power-factor meters are polyphase meters and operate from the same series and shunt transformers as the other instruments. They are a very high-class instrument and indicate accurately the power-factor of either a leading or lagging current or the reversal of power in the circuit. Static ground detectors for single, two or three-phase circuits indicate the presence and extent of a ground on either line. They are connected to the circuit through condensers, but are essentially a high tension instrument and should not be mounted on a switchboard where all the other wiring is low tension or control wiring, as in electrically or distant controlled equipments. Indicating wattmeters of this same type and high class are made and used with the same transformers. Integrating wattmeters are of different form, but have similar connections and register accurately to within two per cent.

BERTRAND BUHRE ABRY

BERTRAND BUHRE ABRY

A TRIBUTE FROM THE ELECTRIC CLUB.

BERTRAND BUHRE ABRY was born October 6th, 1876, and spent his early years in the cities of Cheyenne and Denver. He began his engineering education at the University of Nebraska, which he attended from 1895 until 1899, when he left that university in order to complete his undergraduate studies at the University of Illinois, from which he received the degree of Bachelor of Science in Electrical Engineering in 1900. In the summer of the same year he entered the service of the Westinghouse Electric & Manufacturing Company as an apprentice, working in the factory for two years. In 1902 he entered the engineering department, devoting his attention to railway work. He died, after a short illness, on Monday, October 31, 1904, at the very threshold of a promising engineering career.

His death brings to us as members of The Electric Club a duty and a privilege; the duty of testifying to the value of his work in The Electric Club, and the privilege of offering to his memory our appreciation of the true worth and wholesome influence of his character.

We have all known Abry in his work with us and for us in The Electric Club; first as leader of a section, then as chairman of the Section Committee, and finally as President. His work was characterized by the enthusiasm, the energy and the patience of those who love their task; it was directed by clear thinking; it was made doubly effective by his ability to impart his own enthusiasm to those with whom he worked. The well-defined progression in the value and importance of his service to the club was to a marked degree the direct result of those equally well-defined characteristics of his work.

We have also known Abry as an engineer. His work, before we knew him, had won the respect and admiration of his instructors. He possessed an engineering mind; this, combined with a love of hard work and a determination to get things right no matter what the cost, made his work not only rich in achievement but full of promise. In the words of one his older associates: "He was one of the most promising of our young engineers."

Some of us have had the privilege of knowing Abry as a friend. His ability won our respect—the foundation of friendship; his sincerity, his content to be himself, his moral wholesomeness, ripened respect into friendship—a friendship to be cherished. While those who knew him best have lost most, the whole community has suffered by having Abry taken from it. The world needs men of such character; simple and unassuming, yet strong in individuality and uprightness.

OPPORTUNITIES OF THE APPRENTICESHIP COURSE

A LECTURE BEFORE THE ELECTRIC CLUB

By W. M. MCFARLAND

Acting Vice President of the Westinghouse Electric & Mfg. Co.

I DO not know whether you look upon it as such, but the fact is that the apprenticeship course is in reality a post-graduate course supplementing the theoretical training you obtained in the colleges and universities. You have acquired an acquaintance with the general principles governing engineering, and you now have the opportunity of acquiring intimate practical knowledge of the various details of the manufacture of electrical machinery. The course has been planned with a view to giving the broadest general acquaintance with this practical work, and not with the idea of making skilled handicraftsmen. The education, therefore, is that of the mind and not of the hand.

I cannot too strongly emphasize the opinion held by us older men, that the apprenticeship course offers an unusual opportunity of which thorough advantage should be taken by the apprentices. It is not exaggerating at all to say that you have an opportunity for which many older practicing engineers, if it were practicable, would gladly pay a large sum to enjoy. There is no other way of getting an intimate practical acquaintance with machinery than by daily contact with it in the shop as it is built. I want to urge upon you, therefore, not to neglect this splendid opportunity, but utilize it to the fullest extent, even if you yourselves do not at present realize how great it is. Experience will prove to you later on, that I am understating rather than overstating the opportunities which now lie before you.

It is to be remembered also that in a great technical business like ours it is getting to be more and more the case that all the higher positions must be filled by technically trained men. Even at the present time almost every one of our designing engineers is a graduate of the apprenticeship course; the same is true nearly to the same extent of the correspondence departments; and it is getting to be more and more true every day of the sales department. The engineers of the construction department are, of course, almost without exception, graduated apprentices. While none of the present executive officers are graduates of the apprenticeship course, they are all technical men. I am emphasizing this point to show you that your outlook upon the completion of the course is a bright one, and that, whatever your special aptitude, there is almost sure to be an opportunity for you to utilize it to advantage.

My personal acquaintance with a number of young men who have gone through the apprenticeship course has led me to note that occasionally some are inclined to question the importance of what they consider the drudgery of certain sections of the works, and their anxiety seems to be to hasten through all other sections into the dynamo testing department, where the work is comparatively clean and easy. Now, in my judgment, there can be no greater mistake than this. The work of the dynamo testing department is, of course, very important, but, after all, the same kind of information, though not in so great a degree, can be acquired elsewhere. The knowledge and experience of the details of manufacture which are obtained by conscientious work in other sections of the factory cannot possibly be obtained in any other way.

In what I said a moment ago about openings for the future, I did not speak of the works themselves, but I know it is the belief of some of our management, in which I concur, that the higher works positions offer a fine field for the technically educated man. There must be some among you to whom work of this kind will prove very attractive, so that if this is the case you should pay even more attention to processes as you go through the shop than if your aim were to go into the selling department or some other branch. In other words, for the average man who does not expect to stay in the shop, what he is most anxious to learn is *what* is done in the manufacture of the machines rather than *how*, while the shop man is perhaps more interested in knowing the *how* than the *what*.

For more than one reason I urge you to keep your eyes open and observe carefully everything that is going on about you, including details of shop discipline, shop methods, etc. Whether you make your career with us or go elsewhere, the time will probably come when you will occupy an administrative position of some kind, and then the information you have gained of administrative methods will be of great value to you. The question of cost of manufacture as affected by the speed at which tools are driven, the new and improved tool steels that have been recently introduced, the relative advantages of driving by single motors and in groups, these and many other questions of shop methods are important to many officials of an organization other than these actually in the works. You now have the chance to make yourselves well acquainted with all these points, and you will make a great mistake if you allow this opportunity to go unimproved. Besides the actual information gained you will be training your powers of observation, and this is a most important matter. If time permitted I could tell you a number of very amusing stories respecting mistakes that are made from careless observation. My experience has shown me that young men are apt to pay much more attention to the details of working out the results of observation than to the observations themselves. Of course a little reflection shows that the most important thing of all is accuracy of observation, and you should take every opportunity to train your powers of observation so as to make them thoroughly efficient.

Another opportunity of the apprenticeship course which will never come to you again in life after you have passed to a higher position, is that of acquiring from intimate personal association with workmen their personal point of view. I think we must all realize that in questions of administration and discipline it is a tremendous advantage to the manager to be able to appreciate thoroughly the point of view taken by his men. Too often his only method of doing so is to attempt to put himself in their place and realize how they would look at things. In the apprenticeship course you work with them side-by-side, have a chance to become friends with them and to learn from them what they really think. We know from actual experience the objections put forward by labor agitators to piece-work, the premium system and practically all methods of maximum production. I think most managers believe that this view is not shared by a majority of workmen, and indeed is distinctly opposed to the views of the best and most progressive men. There is also the question of the morale among men, as to such questions as loafing, limiting the amount of work to be done, etc. A manager finds it almost impossible to get the real feeling of the men on these points, but you from your daily association with them and observation of the way they actually behave, can acquire information which will be of the greatest possible value to you later on in life when you, in turn, come to occupy positions of responsibility.

It will not be necessary for all of you, but to some I would say, do not be discouraged by hard work and small pay at the beginning of your active life. It is, of course, a tremendous change from the relative freedom of college life to the daily routine of a manufacturing establishment, and it seems all the harder from the necessity for buckling down to hard work and long hours. Remember, however, that this part of the work is only for a few years, and it is worth while to go through this training for the sake of the immense benefits which come from it. As respects the matter of pay, it is well to remember that in England, so far from young men who are in the shop to learn the details of the business receiving any compensation, they have to pay considerable sums, from $500.00 to $1,000.00 per annum, to have the privilege.

Just a word of caution and also encouragement with respect to some general matters. You have now begun your real life work and will, day by day, be building up a reputation. It is most important therefore, that you should form habits of conscientious attention to duty, zeal and industry. These are of the greatest possible importance to success in life, and obviously habits are only acquired by constant practice. Do not make the mistake of thinking that because the work which you are now doing puts you in a subordinate and unimportant position that it makes no difference whether you do it cheerfully, zealously and intelligently. The habits which you form now will have a decisive effect upon your success in after life, and if you allow yourself to become indifferent and negligent, success will be impossible. I believe that it should be every young man's motto to do the work right at hand as well as he knows how. Do not allow yourself to dream of what you would do if you only had an opportunity to do important things, to the detriment of the simple and unimportant work which is assigned to you. It is safe to say that such dreamers never have the opportunity of doing the greater things which they imagine would arouse their interest.

Many persons not connected with the Westinghouse interests have commented upon the fine esprit de corps that obtains among the representatives of the various companies. I hope that you will all speedily become imbued with this spirit. Doubtless one cause for this is the personality of the remarkable man who has founded these great industries. He is to-day, I believe, the only great captain of industry who is actively at the head of the works which he has built up. History shows that enthusiasm is much more easily aroused by a striking personality that by an abstract principle. I am sure, therefore, that you will all consider it of particular advantage to be enrolled among those who follow the leadership of Mr. Westinghouse. Of course it is impossible for any man who counts more than 20,000 people among his employees to be personally acquainted with even a small fraction of them, but it is nevertheless true that Mr. Westinghouse does take an interest in all that goes on and is on the lookout for specially able men. Some of you are undoubtedly destined in the future to occupy very high places in the company's organization and to become personally acquainted with him. It certainly would be a most laudable ambition for every one of you so to conduct himself that he might hope to be counted as one of the men who was regarded by our chief as destined to become one of the leaders.

ELECTRIC RAILWAY BRAKING

PART III

E. H DEWSON

DETAILS OF THE STRAIGHT AIR BRAKE

THE efficiency and economy of the brake depend in no small degree on the design and arrangement of details such as the cab equipment, the reservoirs, the brake cylinders, etc. The object of all improvements along this line has been to reduce the amount of air needed to stop the car, and to apply this air with a minimum of wear and tear on the brake itself and on the running gear of the car. The increasing attention given to the small parts of the air brake system for the purpose of getting greater economy in the use of air, is one of the many signs of recent progress in electric railroading.

One of the first portions of the brake of which careful study was made was the operating valve, by which the motorman applies and releases the brake. The operating valves now in use with straight air brakes may, for the purpose of discussion, be divided into two classes: rotary valves and slide valves. The most common valve of the rotary type is that used with the Christensen straight air brake equipment, illustrated in Fig. 4.

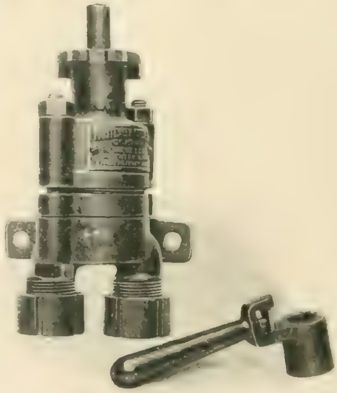
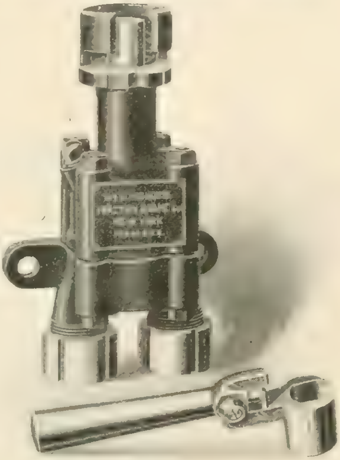


FIG. 4—CHRISTENSEN ROTARY OPERATING VALVE

This valve consists essentially of a seat about two inches in diameter, with three ports leading, in the order mentioned, to the main reservoir pipe, the brake cylinder pipe and the exhaust. This seat is covered by a short cylindrical valve having in its under face two ports which are joined in the interior. When the handle is at the exereme right of its travel the cylinder the main reservoir ports are connected, and both being wide open, an emergency application of the brakes is obtained. Movement of the handle to the left reduces the size of these port openings until they are finally closed, when the valve is in lap position in which there is no connection between any of the ports. A further movement to the left connects the exhaust and brake cylinder ports, thereby permitting the escape of any compressed air previously admitted to the brake cylinder. The greatest advantage of the rotary type of operating valve lies in its low first cost. The principal disadvantage is that the lubricating oil does not distribute itself uniformly over the seat; the valve gets dry and then operates very hard, which necessitates taking the device apart for cleaning and oiling. Furthermore, owing to the unequal travel of the particles situated at varying distances from the center of rotation the surfaces of this valve do not wear uniformly, and require frequent regrinding to keep them tight. The operating handle of the valve is so designed that it can only be removed when the valve is in lap position with all ports closed.



WESTINGHOUSE ROTARY OPERATING VALVE.

The slide valve type of operating valve is considerably more expensive than the rotary valve, but the cost of maintenance is practically nothing, as with it both the above mentioned difficulties are overcome. The interior construction of this type of valve is illustrated in Fig. 5, which shows the device with a portion of the outer casting cut away. The mechanism consists essentially of a plain slide valve operated by a rack and pinion and having in its face a suitable cavity arranged to connect the brake cylinder port at the right with the exhaust at the left when the handle is in release position. In application position the slide valve is moved to the left, thereby uncovering the brake cylinder port. The Westinghouse Company has two forms of this type of operating valve, one with a gauge mounted directly on the head of the valve, the other used with a detached gauge. The removable operating handle of these valves fits into its socket through a slot just below the top plate and swings through an arc of about 130 degrees from the release position at the extreme left to the emergency position at the extreme right. This handle can only be inserted or removed when the valve is in lap position, with all ports closec When removed, the operating mechanism is locked by a sprin bolt and can only be turned again on the insertion of the operatin handle. The principal advantage of the slide valve type of oper ating valve is that it wears itself into place, continually finding it own seat without the necessity of grinding.

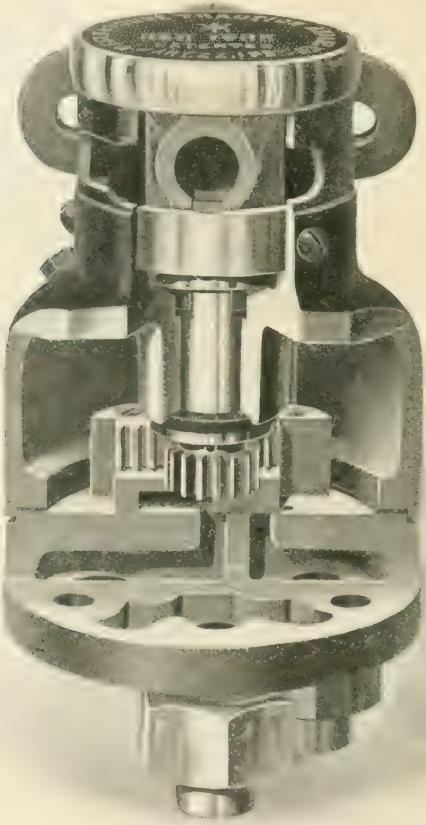


FIG. 5—SECTIONAL VIEW OF AN OPERATING VALVE OF THE SLIDE VALVE TYPE

A good operating valve for the straight air brake should be c a design that will enable a motorman of ordinary skill and inteli gence to manipulate the brake smoothly and without fear of it failing to produce the desired effect. It will secure the best brak ing results with the least amount of air, and it will be durable and easy to maintain. It is possible to apply and release the straight air brake by means of an ordinary three way cock. But aside from the resultant waste of air it would be an impossibility to secure uniform, smooth and regular stops, and the wear and tear on trucks and running gear from the shocks and jars that would follow every application of the brake would render such a crude device quite impracticable.

The various positions of the operating handle should be clearly and definitely indicated to the sense of touch, so that the motorman will know just when he has reached each separate position of the valve without looking.

Cut-out cocks should invariably be placed in the pipe line below each air brake operating valve so that it may be removed in case of emergency or without delay or the loss of air. The exhaust from the operating valve should always be discharged through a muffler, in order to avoid the disagreeable noise caused by air escaping under pressure.

An important portion of every straight air brake equipment is the gauge provided in the cab to indicate to the motorman the air pressure at his command. The best practice requires the use of a duplex gauge showing not only the main reservoir pressure but also that in the brake cylinder. A knowledge of the amount of air he is using for each application is of considerable value to the careful and intelligent motorman in aiding him to economize in the use of air. The gauge should invariably be placed in such a position that it will always be where the motorman can see it easily and without turning his head.

Another form of operating valve shown in Fig. 6 has a duplex gauge mounted on its head and covered by heavy glass, suitably protected. The gauge is therefore constantly under the eye of the operator, making it unnecessary for him to look up or turn his head in a more or less awkward position. A reliable gauge properly located removes any excuse for not instantly knowing, in case of an emergency, how much air is available. If the gauge is not mounted on the head of the operating valve it should be mounted as close thereto as possible. On cars that operate at night an illuminated gauge is sometimes used.

The important factors in computing the size of reservoir for straight air brake equipment were mentioned in the first article of this series, but it will be well to add here a caution that care should be taken invariably to specify a reservoir of a size sufficient to store the requisite amount of air, not only for the brakes but for any air operated auxiliaries which the compressor is to supply. The larger the main reservoir used, the less often will the compressor be cut into action. There will consequently be a reduction in the amount of wear on both compressor and governor, and a lower total current consumption owing to the well-known relation which the starting current of a motor bears to its running current. The main reservoir should invariably be provided with a safety valve to preclude the possibility of overcharging and to protect the motor compressor from being operated against too high a pressure in case the governor should fail to cut it out of operation.

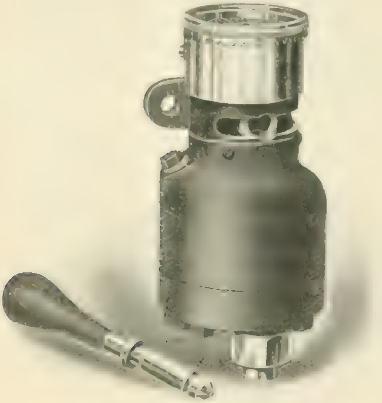


FIG. 6—SLIDE VALVE OPERATING VALVE WITH ATTACHED GAUGE.

The standard brake cylinder adopted by all the air brake companies has a stroke of twelve inches and a diameter varying with the weight of the car. The size of the brake cylinder should be determined with reference to the total light weight of the car, including trucks and motors, and in accordance with formulas that will be discussed in a later article dealing with the subject of brake leverage. The levers constituting the brake rigging should be so adjusted that the piston travel does not exceed from six to seven and a half inches. The distance which the brake cylinder piston is forced outward in applying the brake upon a car that is standing still is spoken of technically as *standing travel*. The distance which the piston is forced outward in applying the brake on a moving car is technically termed *running travel*. Standing travel should be adjusted to about six inches in the case of a brake cylinder with twelve inches stroke. Running travel is always greater than standing travel owing to slack in loose-fitting brasses, shoes pulling down on the wheels, lost motion between the boxes and the pedestals, and numerous other causes that go to increase slack in a brake rigging under the influence of the motion of the car. If standing travel be adjusted to six inches, running travel under ordinary conditions will be about seven and one-half inches.

A great many methods have been devised for automatically securing the uniform adjustment of piston travel on cars equipped with air brakes, with the object of economizing in the quantity of air used, of securing uniform braking effect and of saving the labor of hand adjustment. These devices are of widely different types, varying from special and intricate designs of brake rigging to the use of a small auxiliary brake cylinder that takes up the slack in the rigging before air is allowed to pass into the main cylinder. Fig. 7 shows a slack adjuster which is widely used in electric railway practice. It was originally brought out for use with the automatic air brake on steam railway cars, and automatically maintains a predetermined running travel. This device consists essentially of a small cylinder connected by piping to the air brake cylinder at a point such that no air can enter this pipe until the piston of the brake cylinder has traveled beyond the entrance of the pipe. Assuming, for instance, that seven and one-half inches has been determined as the limit of running piston travel, air can flow from the brake cylinder into the slack adjuster cylinder as soon as the piston of the brake cylinder has passed the pipe connection made at the seven and one-half inch point. The admission of air to the cylinder of the slack adjuster operates a ratchet, which, by means of a screw, draws the end of one of the brake levers away from the brake cylinder, thus taking up all slack beyond that originally provided for proper shoe clearance. The saving of air effected by means of this device will easily be recognized when one stops to consider the amount of air that would otherwise be used to force the piston of the brake cylinder through an extra three or four inches in order to take up the lost motion in the brake rigging and running gear.

Air operated auxiliaries on electric cars are often specified without reckoning on the amount of air required for their operation, it being assumed that the brake compressor can supply these also. The installation of such pneumatic devices then results invariably in unsatisfactory operation of brake, compressor and auxiliaries.

With the introduction of heavy rolling stock and high speeds in electric railway practice the use of air whistles instead of gongs has become quite general. The usual whistle set for a straight air brake equipment consists of a whistle valve and a cut-out cock, in addition to the whistle itself. The best whistles are adjustable for the pressure necessary to secure the required tone and will stand also a considerable range of pressure without changing tone. A whistle set to blow clear at 50 pounds will give practically the same tone at ten or twenty pounds above or below this pressure.

The tendency among motormen is generally toward an extravagant use of the whistle, and in the interest of economy, it is advisable to take every precaution against it. For this reason the best practice does not commend placing the whistle valve under the platform to be operated by the motorman's foot. This invariably leads to a waste of air.

When the installation of whistles on a car is contemplated, a careful estimate should be made of the amount of air that it will be necessary to provide for this purpose. This depends on the size of the whistle, the desired length of signal blasts and the frequency with which the whistle will have to be used. It will not infrequently be found that the amount is so great as to require the installation of a larger compressor. In New England where signals are so frequent owing to numerous stations

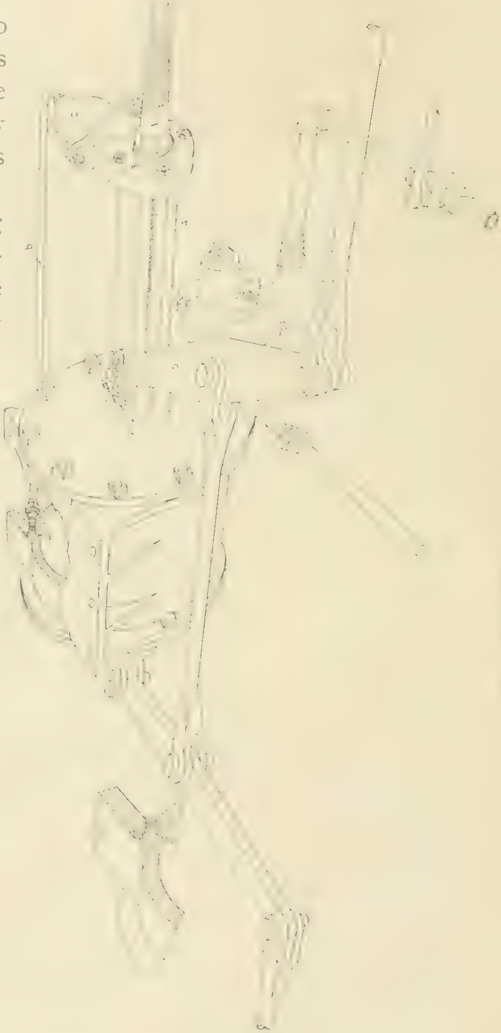
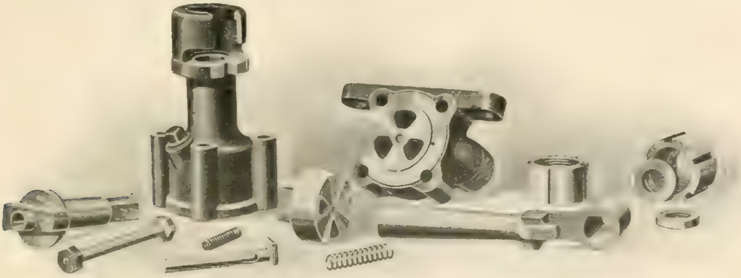


FIG 7—AUTOMATIC SLACK ADJUSTER

and road crossings, there are electric cars in service to-day with whistles of such a size, that the amount of air used for whistling greatly exceeds that used for braking.



PARTS OF A ROTARY OPERATING VALVE.

There are many other pneumatic auxiliaries used on electric cars to-day, and, as a rule, these require a great deal of air for their operation as compared with that necessary for the brake proper. Pneumatic sanders, air operated trolley retrievers, platform gates, pneumatic control apparatus, and systems for maintaining a water pressure to the lavatories, are all in use on modern electric cars. They must all be taken into consideration.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

VIII—THE HEYLAND DIAGRAM

By V. KARAPETOFF

A SERIES OF LECTURES DELIVERED BEFORE THE ELECTRIC CLUB

THE HEYLAND DIAGRAM

Circle of In-put—Having considered the diagram for a definite value of the load, it will be of interest to determine the changes occurring in this diagram throughout a wide range of loading.

Mr. Heyland was the first to point out that the locus of the point A_1 during a variation of the load, is a semi-circle $C_1\ A_1\ K$, Fig. 52, having its center on the line $O\ K$, a continuation of the primary magnetic flux vector $O\ C_1$. This can be demonstrated to be strictly true only on the assumption that the primary ohmic drop $P\ Q$ can be neglected. In this case $O\ Q$ coincides with $O\ P$, Fig. 51. The counter e.m.f. $O\ P$ of the motor, equal to the terminal voltage is constant and the flux $O\ C_1$ producing this counter e.m.f. may be also assumed constant.

Designate the ratio $\frac{O\ B_1}{O\ A_1}$ by n_1, and the ratio $\frac{O\ B_2}{O\ A_2}$ by n_2. The interpretation of these coefficients is as follows: for instance, $n_1 = 0.92$, means that out of every hundred lines of force produced by the primary winding, 92 pass the air-gap and are interlinked with the secondary winding, while the remaining eight constitute the leakage flux. Another meaning of these coefficients is: as the fluxes distribute themselves in a manner which is inversely proportional to the reluctances of the magnetic paths, the leakage coefficient, 0.92, means that the magnetic reluctance of the leakage path is

$$\frac{0.92}{1.00-0.92} = 11.5$$

times higher than the reluctance of the useful magnetic paths.

To prove that the point A_1, Fig 52, moves on a circle, it is only necessary to prove that the perpendicular $A_1\ K$ upon $A_1\ C_1$ at the point A_1, meets the base line $O\ K$ at a point K such that the length $C_1\ K$ is independent of the length or position of $A_1\ C_1$, and can be simply expressed in terms of the primary flux $O C_1$, which is constant, and the coefficients n_1 and n_2 which are also constant.

$A_1 C_1 K$ and $C_2 D O$ are similar triangles. Therefore,

$$\frac{K C_1}{O D} = \frac{A_1 C_1}{D C_2} = \frac{A_1 C_1}{B_1 C_2 - B_1 D}.$$

but $$O D = \frac{O B_1}{O A_1} \times O C_1 = n_1 \times O C_1;$$

$$A_1 C_1 = O B_2 = n_2 \times O A_2;$$

$$B_1 C_2 = O A_2;$$

$$B_1 D = n_1 \times A_1 C_1 = n_1 n_2 \times O A_2.$$

Substituting; $K C_1 = O C_1 \times \dfrac{n_1 n_2}{1 - n_1 n_2}$ or $K C$ is constant.

Thus the right triangle $C_1 A_1 K$ has a constant hypotenuse $C_1 K$, therefore its apex A_1 moves on a semi-circle with $K C_1$ for its diameter. As $O P$ is the direction of the terminal voltage (upon the assumption that the primary ohmic drop may be neglected) the angle $P O A_1$ measures the power-factor of the primary circuit.

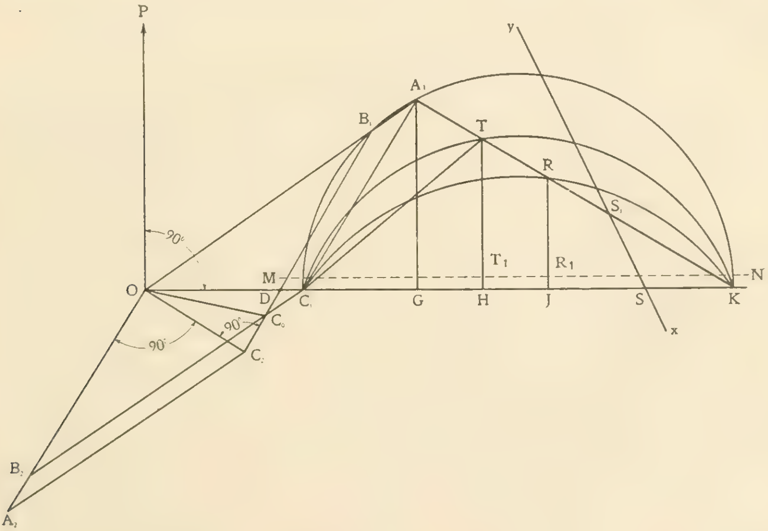


FIG. 52

However rigid the theoretical proof of the Heyland circle may be, its practical accuracy has been established by years of application to actual motors, and may now be accepted as an experimental fact.

Application to an Actual Motor—To demonstrate this, readings should be taken of the primary current and the corresponding power-factor at different loads. Lay these off as shown in Fig. 53, the lengths of the vectors, $O\ C_1$, $O\ C_2$, $O\ C_3$, etc., representing the values of the currents, and the angles $F\ O\ C_1$, $F\ O\ C_2$, etc., corresponding to the power-factors of these loads. It will then be found that the points C_1, C_2, C_3, etc., lie very close to a semi-circle having its center on the base line $O\ B$.

For small motors in which the primary ohmic drop has an appreciable value the extremities of the current vectors will also lie on a semi-circle, but its center is somewhat above the base line $O\ B$. For such small motors the Heyland diagram is not very well adapted. Messrs. Blondel, Ossanne, Bragstad and others have developed diagrams for taking the primary ohmic drop into account and their diagrams give good practical results, but are more complicated than the Heyland diagram though employing the same general principle. The Heyland diagram is the fundamental one, and those familiar with it will encounter no difficulties in understanding the other diagrams. For motors as small as two or three horsepower, the Heyland diagram is sufficiently accurate for all practical purposes.

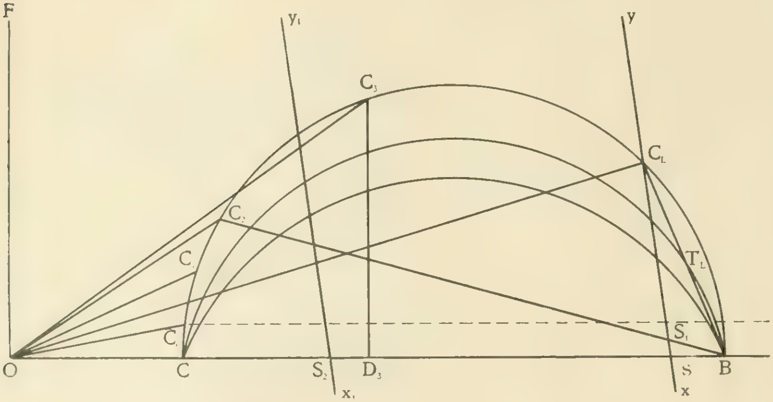


FIG. 53

The Heyland circle is completely determined by any two points on its circumference. The points most easily obtainable from a test are those corresponding to the no-load run C_0 in Fig. 53, and to the readings with the armature locked C_L. This latter test corresponds to the short-circuit test on transformers and generators and in it the total leakage of the motor is manifested in the most prominent way. These two points have the following two advantages over any others, for determining the Heyland circle: (a) They are most easily obtainable experimentally requiring no brake test. (b) They are the most extreme points on the circle having a practical meaning as to limitations. At all loads the end of the current vector travels between C_0 and C_L. Thus any error in determining one of these points effects the determination of any intermediate points to a diminished extent. If convenient it will be of some advantage to observe the readings at the full-load point. This will give three points on the circle which, owing to inevitable errors in the readings of the instruments, will form a valuable check.

The Heyland circle measures not only the primary current at any load but also the apparent and true in-put to the motor. The apparent in-put is equal to $E_1\ I_1$ where E_1 is the impressed voltage and I_1 is the primary current. E_1 being constant, the apparent input is proportional to the primary current, or to the vectors $O\ C_1$, $O\ C_2$, $O\ C_3$, etc., in Fig. 53. Thus the same vectors which represent the primary current, may, with suitable scale, represent the apparent in-put. This new scale can be easily determined. Let, for instance, the scale of the current be ten amperes to the inch and let the voltage of the motor be 200 volts; then each ampere corresponds to an apparent in-put of 200 watts and the scale of the in-put is 2000 watts to an inch. The true in-put is equal to the voltage multiplied by the working component of the current and equals $E_1\ I_1$ CosΦ, or E_1 being constant, it is simply proportional to the working component of the current. This component is equal to the ordinate C_3D_3 of any point C_3 on the scale above the base line $O\ B$, since the angle $F\ O\ C_3$ between the voltage OF and the vector of the current is equal to Φ. Thus the ordinates of the points on the circle measure the true in-put to the motor; the scale being the same as that for the apparent watts, since CosΦ is a ratio having no dimensions.

Mechanical Torque and Speed—The torque, out-put, and speed of the motor can also be represented in this diagram in a simple way. The pull on a conductor in a magnetic field is proportional to the strength of the current in that conductor and the strength of the magnetic field itself. In the case of alternating currents, the phase difference between the current and the field must also be considered since the pull is produced only by that component of the magnetic flux which attains its maximum simultaneously with the current, the other component giving a resultant pull equal to zero during a complete cycle. The torque of any motor is proportional to the armature current times the magnetic flux which is interlinked with the conductors carrying this current. In Fig. 52 $O\ A_2$ is proportional to the secondary current and $O\ C_0$ is the flux in the air-gap. Subtracting the part $C_0\ C_2 = B_2\ A_2$ required to neutralize the secondary self-induction and producing no useful torque, we get the actual flux $O\ C_2$ which acts with the secondary current $O\ A_2$ to produce the torque. This flux $O\ C_2$ attains a maximum simultaneously with the secondary current, because being perpendicular to $O\ A_2$ it corresponds to an e.m.f. in the direction of $O\ A_2$ as has been explained before.

The torque is thus proportional to the product $O\ A_2 \times O\ C_2$; it is also proportional to $A_1\ C_1 \times A_1\ K$, since $A_1\ C_1$ is equal to $n_2 \times O\ A_2$ and $A_1\ K$ is proportional to $O\ C_2$, triangles $A_1\ C_1\ K$ and $O\ D\ C_2$ being similar. It is interesting to note that the product $A_1\ C_1 \times A_1\ K$ represents the double area of the triangle $A_1\ C_1\ K$. The same area can be represented by the product $K\ C_1 \times A_1\ G$ or $K\ C_1$ being constant, we may say that the torque is simply proportional to the ordinate of the point A_1 above the base line $O\ K$.

This ordinate, however, is proportional to the in-put, in an ideal motor, so that the torque is proportional to the in-put. This is only true for an ideal motor having no primary resistance and no primary iron loss. In such a motor the total energy put into the primary would be delivered to the secondary in the form of a mechanical torque between the primary and the secondary. In actual motors the torque is somewhat smaller than it is in an ideal motor owing to the above mentioned losses in the primary. The effect of the primary ohmic resistance is to diminish the counter e.m.f. of the motor, and to diminish all the fluxes in the same proportion. Here-to-fore the primary ohmic drop $P\ Q$ has been neglected. In taking it into consideration, the secondary e.m.f., or the flux $O\ C_2$ and consequently, $A_1\ K$ will be diminished by an amount corresponding to this drop. Let $A_1\ T$ be proportional to the primary ohmic drop, that is proportional to the primary current $O\ A_1$. Subtracting this from all the vectors, as $A_1\ K$, of the diagram we will get a curve $K\ T\ C_1$ differing from a circle and which therefore could hardly be used for practical purposes.

In order to make the curve $C_1\ T\ K$ an arc of a circle, Mr. Heyland made the following assumption, which though not absolutely correct is accurate enough for practical purposes, especially if we remember that the whole influence of the primary ohmic resistance is comparatively small, in the best commercial motors. Mr. Heyland reasoned as follows: The primary current $O A_1$ may be considered as consisting of two parts: $O C_1$ which is constant, and in quadrature with the voltage $O P$, and which represents the magnetizing current: and $C_1 A_1$ which is a variable and represents the secondary current reduced to an equivalent primary current. Take into account, in the part $A_1 T$, only the variable part $A_1 C_1$, of the primary current, adding the constant loss caused by the component $O C_1$ to the other constant losses of the motor (iron loss and friction), these to be considered later. Thus instead of making the correction $A_1 T$, proportional to $O A_1$, make it proportional to $C_1 A_1$. It can be easily shown that in this case the locus of T is an arc of the circle $C_1 T K$ and that the ordinate of T above the base line $O K$ is proportional to the torque. To prove this, connect C_1 and T. The torque is proportional to the product of $C_1 A$ and $T K$ (secondary current times corrected secondary flux), or it is proportional to the area of the triangle $K T C_1$. The same area can be represented by the product of the base $K C_1$ times the altitude $T H$, or $K C$ being constant, this area, and therefore the torque, is simply proportional to the ordinate $T H$. Moreover the angle $A_1 C_1 T$ being constant, since by assumption $A_1 T$ is proportional to $C_1 A$, the angle $C_1 T K$ is also constant for different positions of the point A_1 or T; therefore T lies on an arc of the circle passing through C_1 and K.

The ordinate $T H$ must be further reduced by the amount of the above mentioned constant losses in the motor, diminishing the useful torque available at the shaft. All these losses, being practically independent of the load on the motor, can be taken into account by drawing a line $M N$ parallel to the base line $O K$ and at such a distance from it that it would cut from the ordinate $T H$ a part representing the lost torque. The ordinates of the curve $C_1 T K$ above this new base line will represent the true torque of the motor. This base line passes through the no-load point C_0, Fig. 53, because at no load there being no useful torque available the ordinate of C_0 represents the torque lost by the primary ohmic drop of the magnetizing current and by the primary iron loss and friction.

Output— In an ideal motor having no primary or secondary resistance and no iron loss and friction loss, the input would be equal to the output, and the speed being synchronous at all loads (since the secondary resistance is zero) the torque would also be proportional to the input or the output. Thus in an ideal motor, input, torque and output would be represented by the same ordinate A_1G, Fig. 52. Because of the primary ohmic drop, approximately represented by A_1T, the torque is reduced to a value represented by $T\ H$. The output is further reduced by the secondary ohmic drop. Laying off $T\ R$ equal to this drop, we get an arc of another circle, $C_1R\ K$ whose ordinates as $R\ J$ represent the output to the same scale as $A_1\ G$ represents the input. In an ideal motor both A_1T and $T\ R$, equal zero, and the three circles coincide. The higher the resistances of the windings, the further apart are these circles, and the torque and the output of the motor are correspondingly reduced. To take the primary iron loss and friction into account, the ordinate $R\ J$ must be further reduced by the amount R_1J as was explained for the ordinates of the torque.

Consider the three circles to have been constructed and the line $M\ N$ drawn. To find the performance of the motor corresponding to a given primary current $O\ A_1$ draw the line $A_1\ K$ and measure the ordinates A_1G, $T_1\ T$, and R_1R, which give respectively the input, torque and output of the motor.

When the point A_1 moves to the right on the circle, the primary current increases; and the output also increases, up to a certain maximum point, and then diminishes as the motor speed approaches zero. At zero speed the output is zero, therefore the ordinate $R\ J$ and also the length $R\ K$ must be zero, so that at the point on the curve corresponding to armature locked, $A_1\ K$ is tangent to the circle, $C_1\ R\ K$ at the point K. As has been explained before, the first circle of the Heyland diagram (circle of input) is usually determined from the no-load current and the locked current (C, and C_L in Fig. 53). The third circle (the circle of output) is easily found by connecting C_L to B and drawing an arc of a circle passing through B and C and tangent to $C_L\ B$ at B. The segment $C_1\ B$ in Fig. 53 has the same meaning for the locked point as A_1R, in Fig. 52, for an intermediate load. Therefore the second circle (circle of torque) divides $C_1\ B$ at the point T_L in the ratio of the primary to the secondary resistance, the latter being reduced to terms of the primary circuit, as in the case of transformers. [See August issue, page 413.] The following cases occur in practice regarding the determination of the point T_1, which in its turn determines the second circle:

First. Motors with squirrel cage secondary—Knowing the primary ohmic resistance, r_1 and the primary current I_L with the armature locked, the primary ohmic drop $r_1\ I_L$ becomes known. Lay off

$$C_L\ T_L = OB \times \frac{r_1\ I_L}{E_1}$$

which determines the point T_L on the second circle. This construction can be explained as follows:

In Fig. 52 the vector $C_1\ O$ represents the total primary flux which, neglecting the primary ohmic drop, can be assumed as proportional to the total primary impressed voltage E_1. From this flux the primary leakage flux $C_1 C_0$ and the secondary leakage flux $C_0\ C_2$ are subtracted. The remainder $O\ C_2$ represents what may be called the working component of the flux, partly transformed into useful work and partly absorbed by the ohmic resistance of the motor. $O\ C_1$, and therefore $O\ C_2$, being proportional to E_1, the part absorbed by the primary ohmic resistance for any given current I_1, is equal to

$$O\ C_2 \times \frac{r_1\ I_1}{E_1}$$

Instead of using the triangle $O\ C_1\ C_2$, use the approximately similar triangle $O\ A_1\ K'$, and subtract from $A_1\ K$ which corresponds to $O\ C_2$, the segment $A_1\ T = O\ K' \times \frac{r_1\ I_1}{E_1}$. At the locked point, $C_L\ T_L$, Fig. 53, corresponds to the primary ohmic drop $A_1\ T$ Fig. 52, and so with the notations of Fig. 53 we get $C_L\ T_L = O\ B \times \frac{r_1\ I_1}{E_1}$. As has been explained before, this is not quite correct, but is entirely justified by practice, since the total influence of the ohmic drop in good motors is very small.

Second. Motors with phase wound secondary, provided with slip rings.—Inserting ammeters in both the primary and secondary circuits, the primary and secondary ohmic drop can be determined separately; resistances of the windings having been previously measured with direct-current. Reducing the secondary resistance to the primary circuit, the point T_1 can be found by dividing $C_1\ B$ in the ratio of the primary and secondary resistances.

Let, for instance, the resistances be 0.37 ohms for the primary and 0.115 ohms for the secondary, and let the corresponding currents, with the armature locked, be 65 amperes and 122 amperes. The secondary resistance reduced to the primary circuit is

$$0.115\left(\frac{122}{65}\right)^2 = 0.404 \text{ ohms.}$$

As for transformers, we have: $C_L\ T_L : T_L\ B = 0.37 : 0.404$.

It is advisable to check up the position of the point T_L by the method indicated above for motors with squirrel cage secondaries. In most cases there will be some discrepancy in the two methods, due, most probably, to the influence of eddy currents when the armature is locked. The difference, however, ought not to be great and the average position of the point T_L should be used.

Third. Large Motors.—With very large motors, the locked test cannot be performed in the above manner because of too heavy currents which would damage the motor; the better the motor, the larger are these currents. It is therefore necessary to perform this test at less than full voltage and also to have some additional resistance in the secondary. For instance, let a test on a 6,600-volt motor be performed at 4,500 volts with some additonal resistance in the secondary and let the results be: primary current 324 amperes, secondary current 765 amperes, primary ohmic resistance 0.47 ohms; total resistance of the secondary circuit, including secondary winding, rheostat, ammeter, switches, etc., 0.23 ohm; resistance of the secondary windings alone 0.084 ohm. From these data the positions of the second and third circles of the Heyland diagram can be determined as follows: First of all the currents must be reduced to the normal voltage of 6.600. Due to the fact that all alternating current apparatus is usually designed for a comparatively low magnetic saturation in the iron and that this saturation is particularly low on the locked test, the currents can be assumed as directly proportional to the impressed voltages. Actual experience justifies this assumption. Thus at full voltage the currents would be:

Primary winding............$324 \times \left(\frac{6600}{4500}\right) = 475$ amperes.

Secondary winding.........$765 \times \left(\frac{6600}{4500}\right) = 1122$ amperes.

The total secondary resistance reduced to the primary is:

$$0.23\left(\frac{1122}{475}\right)^2 = 1.28 \text{ ohms.}$$

and the point T_L is determined by the relation

$$C_1 T_1 : T_1 B = 0.47 : 1.28.$$

If there be no additional resistance in the secondary, the third circle would be tangent to the line $C_L B$ Fig. 54. In this case, however, the external and internal resistances of the secondary

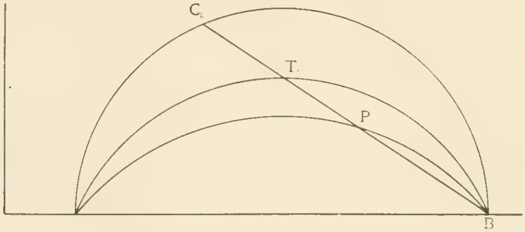


FIG. 54

must be separated, the latter only being necessarily taken into account for the actual operation of the motor. Thus we divide $T_L B$ at P_L so that

$$T_L P_L : T_1 B = 0.084 : 0.230.$$

and draw the circle through the point P_L. The part $P_L B$ of the magnetic flux is transformed into heat in the external resistance and under actual conditions of running it would have been transformed into actual mechanical work. Kapp was the first who pointed out that the effect of the primary is the same whether a definite amount of work is supplied by the revolving motor to the shaft in the form of mechanical energy, or by the motor standing still to an additional secondary resistance in the form of heat, this resistance being non-inductive.

SLIP. According to the general law of induction the e.m.f. induced in a winding is proportional to the value of the inducing magnetic flux and to the frequency at which the lines of force cut the conductors of the winding. The e.m.f. induced in the secondary of an induction motor is proportional to flux $O C_2$, Fig. 52, and to the slip of the motor, or the slip is proportional to the ratio:

$$\frac{\text{secondary current}}{\text{useful secondary flux}}$$

The secondary current is represented in the diagram by the vector $C_1 A_1$, Fig. 52, and the secondary flux $O C_2$ corrected for the primary ohmic drop is represented by $K\ T$. Thus the slip is proportional to the ratio :

$$\frac{C_1\ A_1}{K\ T}$$

Instead of representing the slip as a ratio it may also be represented as a segment of a line. Draw any line $x\ y$ such that the angle $y\ S\ K$ is equal to the constant angle $K\ T\ C_1$. The triangle $S_1\ SK$ is similar to the triangle $C_1T\ K$ so that the slip is also proportional to the ratio $\frac{S_1\ S}{K S}$, or $K\ S$ being constant, the slip is simply proportional to S_1S. To find the absolute value of the slip in per cent draw the line $x\ y$ so that it will pass through the locked point C_1 Fig. 53, at which the slip is evidently 100 percent and divide $S\ C_L$ into 100 parts. Then any vector as C_2B cuts this line in a point S_1 such that the segment $S\ S_1$ represents the slip in per-cent, $S\ C_L$ being equal to 100 per cent.

With good commercial motors the slip is comparatively small, so that it could not be read off accurately enough on the line $C_L\ S$ it can, however, be read on any other line $x_1\ y_1$ farther to the left in the diagram, the scale being reduced in the ratio $B\ S_2$ to $B\ S$. It is also evident that the slip is proportional to the ordinate of the point S_2 above the base line $O\ B$, the ordinate of C_L being equal to 100 percent. If the diagram is drawn on a sheet of cross-section paper, it is easier to read off the ordinates than to measure the length in a slant direction.

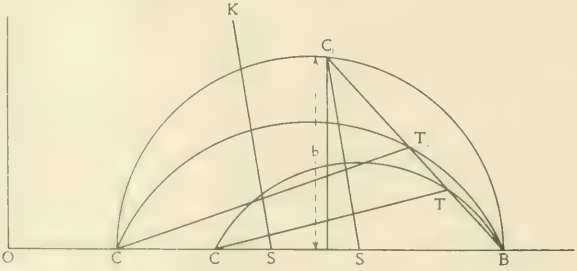


Fig. 55

A disadvantage of the Heyland diagram in the form described above, is that every line measured in it must be multiplied by some fractional constant in order to get actual values of horse-power, foot-pounds, etc. This can be obviated by slight changes in the construction so that all quantities are brought to the scales corresponding to the divisions of cross section paper. This can be done as follows:

(a) *Input and Output.* Instead of laying off the no-load current and the locked current in amperes to determine the first circle of a diagram, lay off the same vectors in apparent horse-power. Then the first and the third circles of the diagram will give directly the horse-power input and output. For instance, supposing the no-load current to be 10.5 amperes and the current with the armature locked 85 amperes. The first circle could be conveniently constructed to a scale of 5 amperes to the inch and the power read in amperes. Instead of doing this, calculate the apparent horse-power corresponding to the above, as follows:

$$10.5 \times \frac{400}{746} = 5.63 \text{ hp.}$$

$$85 \times \frac{400}{746} = 45.6 \text{ hp.}$$

where the voltage of the motor is 400. Lay off the above vectors to a convenient scale such as 2½ hp. to the inch. If desired, another circle can be drawn for the amperes on the same diagram.

(b) *Torque.* If a scale of 1 inch=m horse-power be selected for this first circle, the scale for the second circle, $C\ T_L\ B$, Fig. 55, is

$$1 \text{ inch} = \frac{33{,}000}{2\pi} \times \frac{m}{N} \text{ foot pounds.}$$

Where N is the synchronous speed of the motor. For any other circle as $C_1P_L\ B$, Fig. 55, drawn so that C_1P_L is parallel to $C\ T_L$, the scale will be:

$$1 \text{ inch} = \frac{33{,}000}{2\pi} \times \frac{m}{N} \times \frac{T_L\ B}{P_L\ B}$$

The length $B\ P_L$ can be selected so as to make this scale a convenient even number. Supposing, for instance, the scale of horse-power to be, one inch equals 2½ hp. the synchronous speed of the motor N equals 1,200 r.p.m. and the length $B\ T_L$ equals 6.42 inches. Then by taking $B\ P_L$ equal to 7.02 inches, the scale of torque will be:

$$1 \text{ inch} = \frac{33{,}000}{2\pi} \times \frac{2.5}{1{,}200} \times \frac{6.42}{7.02} \quad 10 \text{ foot pounds.}$$

(c) *Slip.* As was explained before, the slip can be read on the line $C_L\ S$, Fig. 55, or on any line $K\ S_1$ parallel to it. The following formulae permits the selection of the distance S_1B so as to get an even scale for the slip. With the notation of Fig. 55 we have:

1 inch corresponding to $\frac{100}{b}$ percent slip for the line $C_L\,S$.

1 inch corresponding to $\frac{100}{b} \times \frac{S\,B}{S_1\,B}$ percent slip for the line $K\,S_1$.

But the triangles $C\,T_L\,B$ and $C_L\,S\,B$ being similar,

$$\frac{S\,B}{b} = \frac{T_L\,B}{C\,C_L} \text{ and } \frac{1}{b} = \frac{T_L\,B}{S\,B \times C\,C_L}$$

Thus the scale for the line $K\,S_1$ is

$$1 \text{ inch corresponding to } \frac{100}{C_L\,C} \times \frac{T_L\,B}{S_1\,B} \text{ percent slip.}$$

The length S_1B can be selected so as to make the right side of this equation a convenient even number. It is understood that the slip is measured by the ordinates of the line $C_L\,S$ or $K\,S_1$ above the base line $O\,B$ and not by the slant lengths of these lines. This method of drawing the slip line has a particular advantage for large motors where the point S comes comparatively close to B and the segment $S\,B$ is very small. With the usual method of drawing the line S_1K, its scale is made dependent on the ratio $\frac{S_1\,B}{S\,B}$. If $S\,B$ is small and cannot be measured in the diagram with sufficient accuracy, the scale of the line $K\,S_1$ is also very unreliable. With the improved method described above, it is not necessary to measure the line $S\,B$, the scale of the line $K\,S_1$ being made dependent upon the ratio $\frac{T_L\,B}{C\,C_L}$ which segments are always large enough to be closely measured.

By this improved method all the values can be represented in the diagram to a convenient scale and even to the same scale as that used on the corresponding curve sheet, so that plotting performance curves from the diagram is simply reduced to taking certain segments in the diagram and transferring them to the curve sheet without any intermediate calculations or changes of scale. The diagram thus represents the characteristic properties of the motor as clearly as a sheet of performance curves.

FACTORY TESTING OF ELECTRICAL MACHINERY—XI

By R. E. WORKMAN

REGULATION TEST OF ALTERNATOR LOADED ON RESISTANCES, INDUCTIVE OR NON-INDUCTIVE.

Preparations for Test. This test is made in practically the same way as the corresponding test on a direct-current machine. The machine to be tested is belted to a direct-current motor of suitable capacity. The connections for the case of a three-phase alternator are shown in Fig. 59, where the load is connected in star. The test table used is the same as that shown in Fig. 55.

In the case of the smaller alternators of high voltage (1,000 or 2,000 volts), step-down transformers are used between the alternator and the load. These transformers are arranged to transform from three-phase high tension to two-phase low tension, if desired, thus making it possible to load a three-phase machine on two racks. Where two-phase machines are tested the transformers are separately connected to the two phases and to the two racks. In the case of larger alternators a large rack is used, being connected to the alternator as shown in Fig. 60.

Conduct of Test. The plant is started up as in the case of a direct-current machine and the load is applied by adjusting the resistance in each rack, the aim being to keep the resistance of the three legs of the star equal, for each load. In the case of a machine which is not compensated the load current is brought up to its full value and the separate field current adjusted to give the proper terminal voltage. In the case of a compensated machine, as mentioned above, two tests are taken:

(a) Constant Potential Regulation. The separate field current is set so as to give full voltage at no load, and, at each reading, the compensator brushes are moved so as to obtain constant potential.

(b) Maximum Compensation. The separate field current is set as before to give full voltage at no-load and the compensator brushes are set so as to give maximum compensation. The compen-

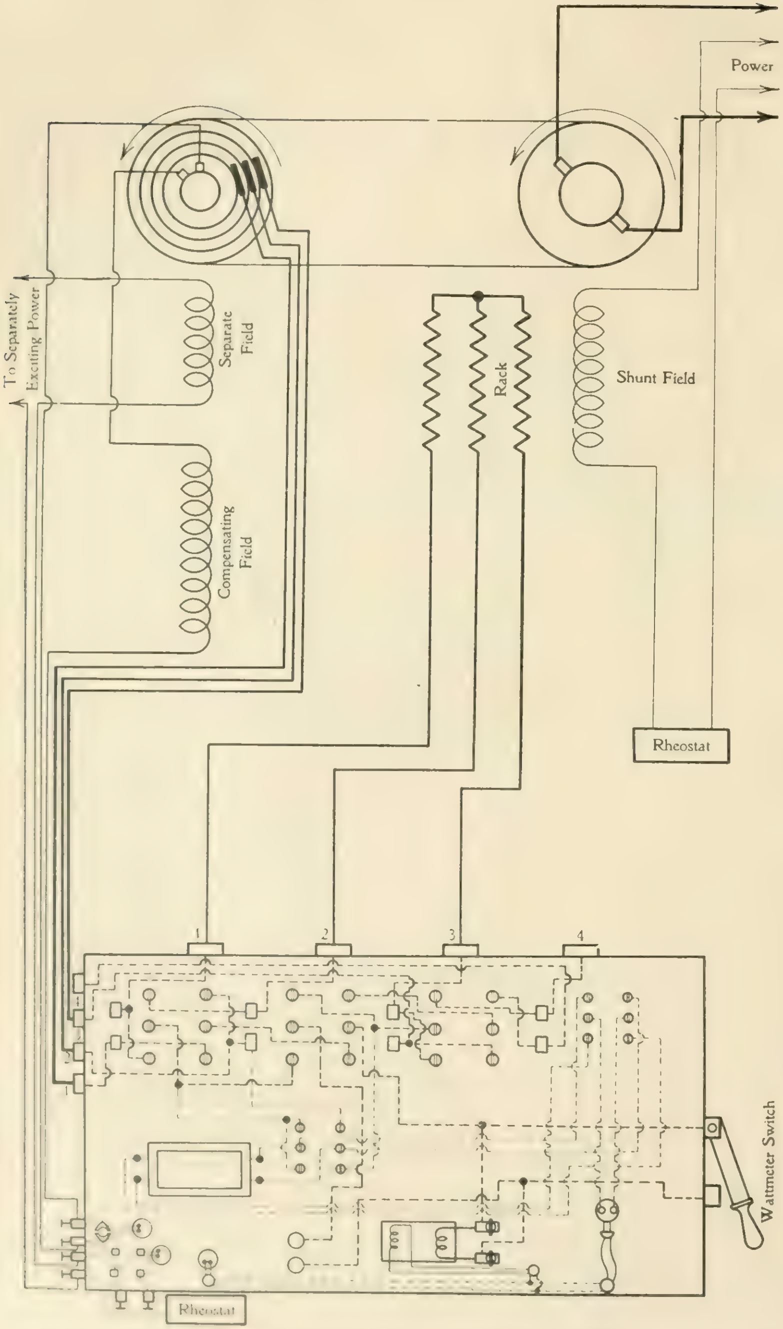


FIG. [illegible].—CONNECTIONS FOR A THREE-PHASE ALTERNATOR; LOAD CONNECTED IN STAR sator brush-position is held constant throughout the test. In all cases the speed is held constant throughout the test.

The readings taken are terminal volts, main amperes, watts (where it is desired to know the power-factor), separate field amperes, compensator-field volts and amperes, and the speed A range of readings is taken from no-load to something well over full-load. In the case of a two-phase machine, the only difference is that one phase and one rack are connected across the terminals 1 and 3 on the table and the other phase and rack across 2 and 4.

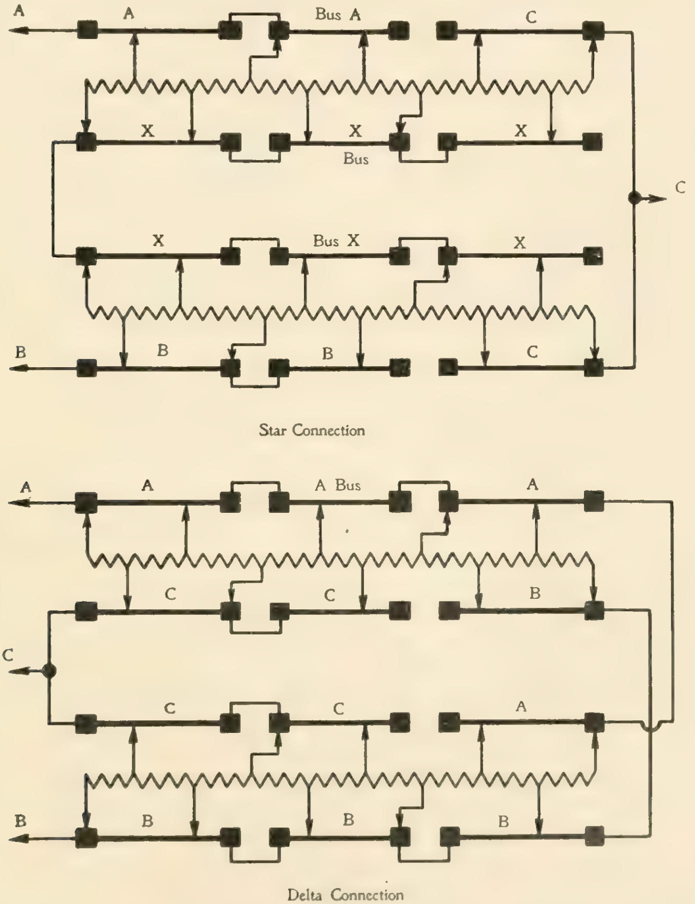


FIG. 60—STAR AND DELTA CONNECTION OF RACK FOR RESISTANCE LOAD ON LARGE MACHINES.

Working up Results. The readings taken after having been corrected for calibration of the instruments, are plotted as shown in Fig. 61, which gives a set of regulation curves for a 120 kw, 60-cycle, 10-pole, 2-phase, 440-volt, generator, run at a power-factor of approximately 80 percent. The power-factor is found by calculating the ratio of the watts output, *as measured on a wattmeter, to the volt-amperes apparent output.

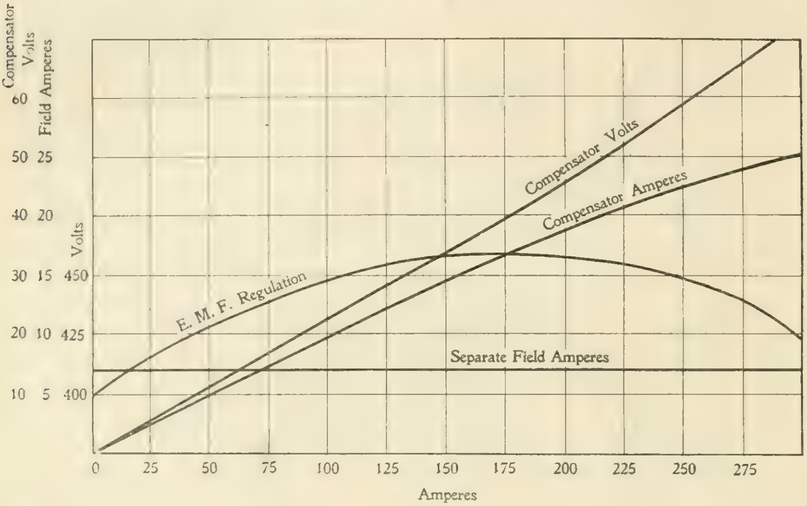


FIG. 61—REGULATION CURVES OF A 120-KW GENERATOR, 60-CYCLES, 10-POLES, 2-PHASE, 440-VOLTS

Where it is desired to take a regulation of an alternator, by loading it on a synchronous motor or motors, the alternator connections and general arrangement will be just the same as for a test on resistance load. Special arrangements, however, must be made for starting the motor, and this would generally be done in something like the following manner. The lines from the alternator would be carried to the terminals at the end of the table in Fig. 55, and the lines from the synchronous motor to those in the front of this table. In order to synchronize the motor it would generally be necessary to belt a small direct-current motor to it, to bring it up to speed. The connections of the synchronous motor, etc., are shown in Fig. 64. In synchronizing the two alternating current machines, it will be well to use two series of lamps, each containing a sufficient number of lamps to stand double the voltage at which the machines are to be synchronized. Lamps are used in preference to a synchronscope because of their greater adaptability to the work of the testing department. When a synchroscope is used for the first time in synchronizing two machines, lamps have to be used to determine whether it is connected in the correct way. The synchroscope is thus better adapted to permanent installations. Where the voltage is too high for the use of a series of lamps, transformers may be used with their high-tension sides across the switches and their low-tension sides across the lamps. Machines may also be synchronized, phase by phase, with the aid of only one series of lamps, as will be described. Where two series of lamps are used, they are connected across the switches S_2 and S_3.

---

*The measurement of power in polyphase circuits by single phase wattmeters:

(1) Two-phase. Power is measured by adding two wattmeter readings, one measuring the power in each phase.

(2) Three-Phase. Referring to figures 62 and 63, which refer to star and to delta connections respectively, consider the current as entering the circuits by the lines 1 and 2 and returning by the line 3. This assumption is justifiable since the current in 3 is equal in magnitude to the resultant of the currents in 1 and 2. Considering the circuits in this light, it will be seen that the power at any instant will be $i_1 e_{1-3} + i_2 e_{2-3}$, where i_1, i_2, e_{1-3}, e_{2-3} are instantaneous values of current and e.m.f. Hence, if two wattmeters are connected with their series coils in the lines 1 and 2, respectively, and their shunt coils across 1-3 and 2-3 respectively, the sum of their readings will be a measure of the power.

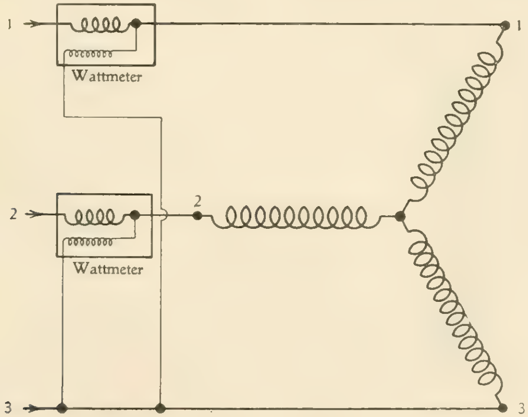


FIG. 62—POLYPHASE POWER MEASURED BY SINGLE-PHASE WATTMETERS, STAR CONNECTION

Conduct of Test. All the switches on the polyphase test table should be open. The motor which is to drive the alternator, also the one which is to be used, first to bring the synchronous motor to speed, and then to load it, may be started successively, in the usual manner. The separate field circuits of the alternating-current machines may then be closed and the voltages of both brought to about

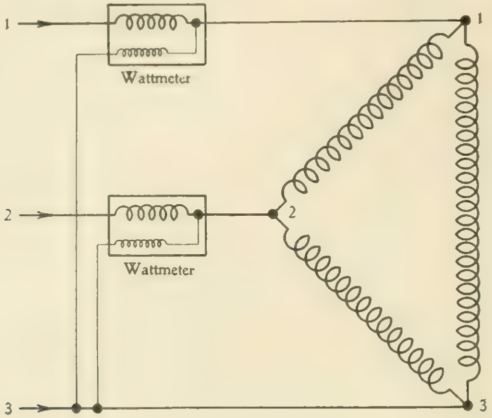


FIG. 63—POLYPHASE POWER MEASURED BY SINGLE-PHASE WATTMETERS, DELTA CONNECTION

the same value, which may be something like half the full voltage of the machines. The speed of the alternator should be brought as nearly as possible to its correct value, by adjusting the field current of its driving motor. The speed of the synchronous motor should be made to correspond closely to the frequency of the alternator. The switch S_1 may then be closed and the two machines synchronized with the aid of the lamps. The two sets of lamps will be seen to fluctuate in brightness, the fluctuations becoming slower and slower as synchronism is approached, the lamps soon alternating between absolute darkness and a maximum brightness. If the two series of lamps are seen to be bright at the same time, it may be at once concluded that the machines are correctly connected and it will be necessary simply to adjust the relative speeds of the machines till the fluctuation is very slow, and, when both sets of lamps are dark, to throw in the switches S_2 and S_3, completing the circuits. If, on the other hand, it is found that one set of lamps is bright when the other is dark, the machines are connected wrong and their field circuits must be opened so as to make it possible to reverse one pair of the motor leads. When the machines have been successfully synchronized the field of the motor driving the synchronous motor should be raised until its current is very small and its circuit breaker then tripped. If it is desired to dispense with one set of lamps, the set used may be connected across the switch S_2 and the machines synchronized as before, the switch S_2 being thrown in. The lamps must then be tried across S_3 to see if the phase relation is correct. If they do not light up the switch S_3 may be thrown in. If the lamps do light up, the motor connections must be changed as before.

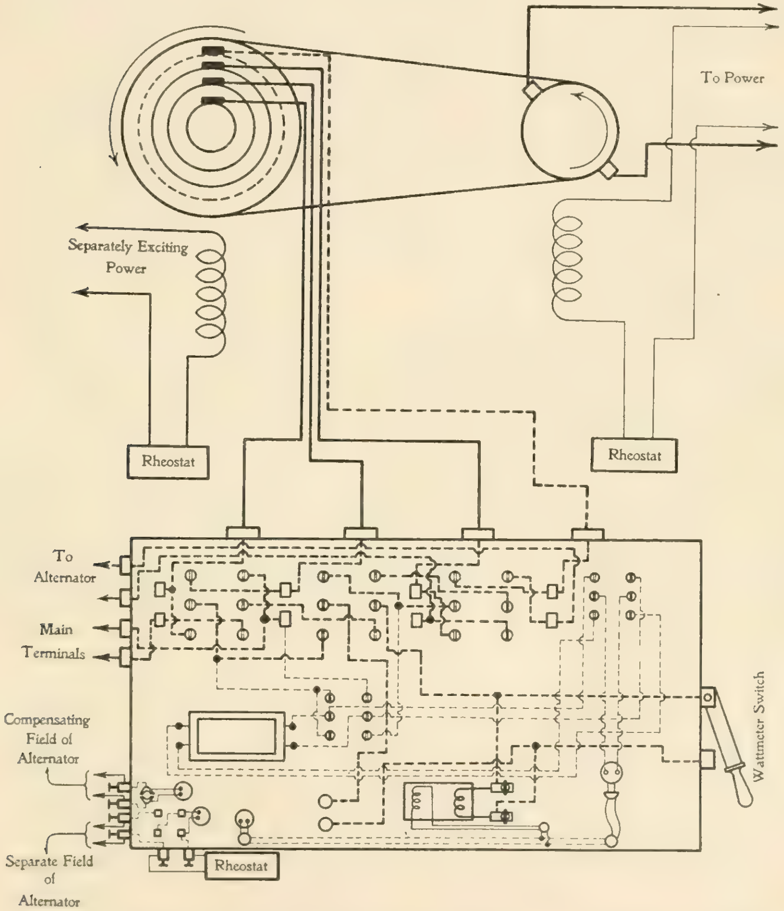

To Power
Separately Exciting Power
Rheostat
Rheostat
To Alternator
Main Terminals
Compensating Field of Alternator
Wattmeter Switch
Separate Field of Alternator
Rheostat

FIG. 64—CONNECTIONS FOR TAKING THE REGULATION OF AN ALTERNATOR LOADED ON A SYNCHRONOUS MOTOR

Where two-phase machines are to be synchronized, it is most convenient to synchronize the phases separately. The machines are started up and brought to speed, as before, and the lamps placed across the switch S_2. The two phases are, of course, connected to the terminals, 1 to 3 and 2 to 4 of the test table, respectively. The switch S_1 is first thrown in and when the machines have been brought to synchronism as indicated by the lamps the switch S_3 is thrown in. The lamps are then tried across either of the switches S_2 or S_4, and, if they do not light up, these switches are closed.

The regulation test may then be made, much as if the alternator were loaded on resistances. The power-factor is held constant by adjusting the field of the synchronous motor, which has the well known property of acting as a capacity in a circuit when its field is over-excited and of acting as an inductance if its field is under-excited. The power-factor may be measured by taking simultaneous readings of volts, amperes and watts on the alternator.

Precautions to be Observed. It is very important to see that the two alternating-current machines are running at the same frequency and in phase with one another, at the instant when their main circuits are closed, otherwise a very large current will pass. If it should happen that the machines are thrown in at the wrong time, the main switches must not be opened again as a dangerous arc might be the result, but if the machines do not pull into step the field on both the alternating current machines should be brought down to a very small value after which the direct-current machines may be stopped.

SYNCHRONIZING OF ALTERNATING CURRENT MACHINES

AN ELEMENTARY EXPOSITION.

TWO machines, an alternator and a rotary converter, for example, are said to be in synchronism when their frequencies are the same and when their phase relation is the same.

The two machines will have the same frequency when the numbers of alternations or reversals of their e. m. f.'s in a given time are equal.

This condition will be fulfilled when the product of the number of poles by the revolutions per minute is the same for each machine.

The two machines will have the same phase relation when the positions of the armatures with respect to the field poles are the same, i. e., when similar armature coils are opposite similar field poles at the same instant.

In addition to being in synchronism with the generator to which it is to be connected, the rotary converter must have approximately the same voltage as the generator. This voltage may be measured by a voltmeter.

The operation of synchronizing, for instance, a rotary converter with a generator, is as follows: The rotary converter is brought up to approximately synchronous speed and its voltage adjusted to that of the generator, then, when the inevitable fluctuation in the speeds of the two machines brings them in phase, they are thrown together. When the two machines have the same frequency, the same phase and the same voltage, there will be no unbalanced e.m.f. and consequently no rush of current when the machines are connected together.

In synchronizing two machines it is evidently necessary to have some means for determining when the frequency and phase position of the incoming machine are right. The principle of the most common method of doing this is shown in Fig 1.

A and B each represent a single-phase machine or one phase of a polyphase machine. The leads of both machines are connected to the switch C, through two series of incandescent lamps, D and E.

It is evident that as the relative positions of the phases of the electromotive forces change from that of exact coincidence to that of exact opposition the flow of current through the lamps varies from a minimum to a maximum. If the electromotive forces of the machines are in phase and of the same value, the current through the lamps will be zero. But as the difference in phase increases, the lamps will light up and increase in brilliancy until the maximum is reached, when the phases are in exact opposition. From this position they will decrease in brilliancy until dark, indicating that the machines are in phase again. The rate of this pulsation of the lamps depends on the relative frequency of the machines to be synchronized. If this rate is reduced to about one pulsation in ten seconds, ample time will be allowed for closing the circuit.

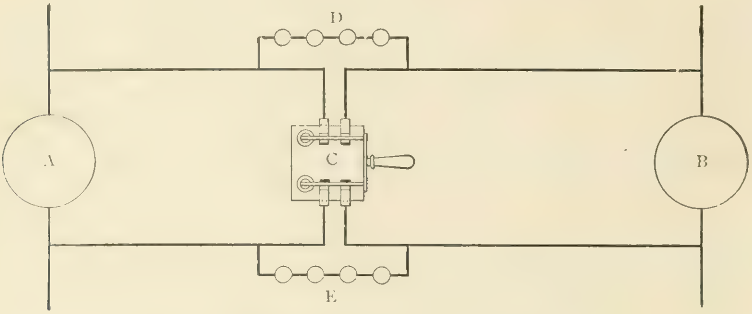


FIG. 1—LAMP METHOD OF SYNCHRONIZING

The synchronizing device instead of being connected directly across the two circuits may be connected in the secondary circuit of two shunt transformers as shown in Fig. 2. There are two transformers, the primaries of which are connected across the generator circuit and rotary converter circuit, respectively, and the secondaries of which are connected in series through the lamps or other synchronizing device. If the transformers are connected similarly in the two circuits there will be no current through the lamps when the machines are in phase, since the induced currents in the transformers will be opposed as shown by the arrows in the diagram. When the machines are out of phase the electromotive forces will be out of phase also and current will flow through the lamps, the amount of the current and the resulting brilliancy of the lamps depending on the difference in phase. If the connections of either the primary or secondary of either transformer be reversed from those shown in the diagram, the indications of the lamps will be reversed; that is, when the machines are in phase the lamps will now burn at maximum brilliancy. In common practice the transformer connections are so made that the lamps will be dark when the machines are in phase.

In order to determine whether the synchronizing lamps will be bright or dark when the machines are in phase, raise the alternating-current brushes from the collectors of the rotary converter and close the alternating-current switches. Since the primaries of both transformers are now connected to the alternating-current line the synchronizing circuit will be operating under the same conditions as when the main switches are open and the rotary converter is in phase with the line. If the lamps burn brightly, and it is desired that they be dark for an indication of synchronism, the connections of one of the primaries or one of the secondaries of one of the transformers should be reversed. The lamps should be adapted for the highest voltage which they will receive. If they are placed upon the secondaries of two 100-volt transformers, there should be two 100-volt lamps or four 50-volt lamps in series.

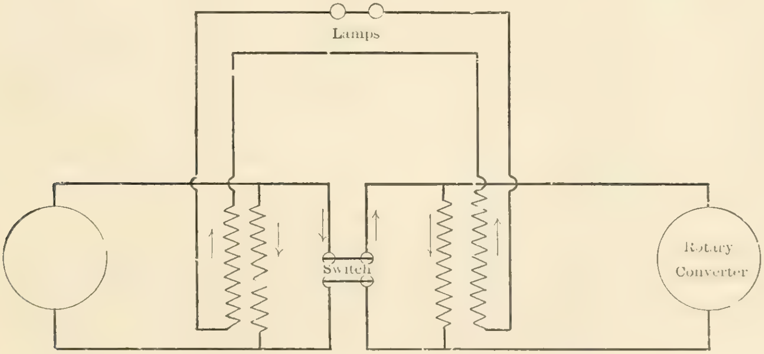


FIG. 2—TRANSFORMER AND LAMP METHOD OF SYNCHRONIZING

Lamps are commonly used as the synchronizing device, but they are objectionable for the reasons that it requires a large difference of phase to make them glow and that they do not distinguish between a machine running too fast and one running too slow.

The ideal synchronizer should perform three distinct functions.

(1) It should indicate whether the incoming machine is running too slow or too fast.

(2) It should indicate the amount by which the incoming machine is too slow or too fast.

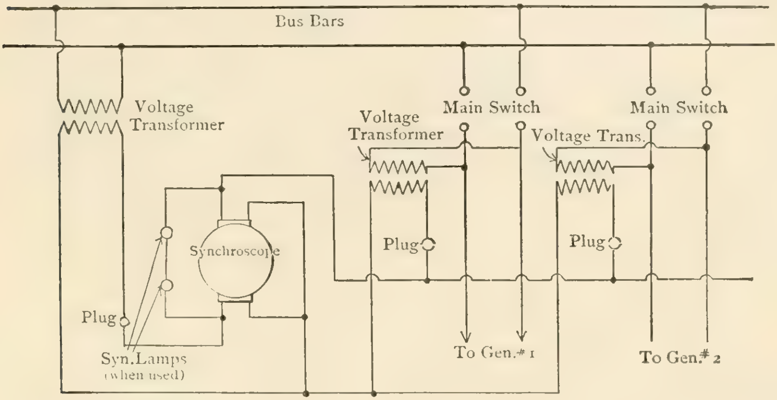
(3) It should indicate the exact time of synchronism or coincidence in phase between the bus bars and the incoming machine.

SYNCHROSCOPE

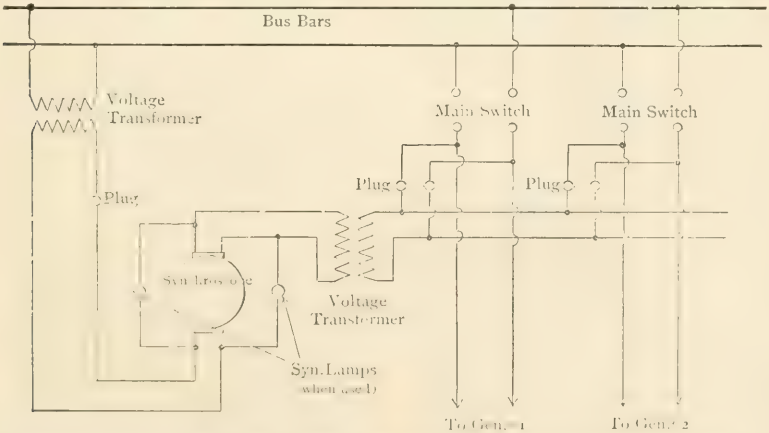
These functions are excellently performed by an instrument known as the synchroscope, which is herewith illustrated. The instrument is provided with an indicating pointer. The phase angle between the converter and the generator is always equal to the angle between the pointer and its vertical position marked on the dial of the instrument. If the frequency of the incoming machine is higher than that of the line, this angle will vary, causing the pointer to rotate in one direction. If the incoming machine is lower in frequency, the pointer will rotate in the opposite direction. FAST and SLOW on the dial mean that the frequency of the machine is higher or lower than the frequency of the line. When the frequency of the machine is equal to that of the line the pointer stops at some position on the scale, and when the machine is in phase with the line the pointer coincides with the dummy pointer at the top of the scale. The main switch may then be closed.

Two shunt transformers are necessary to connect the instrument to the bus bars and one additional shunt transformer to connect it to each machine to be synchronized. When installed the same shunt transformers may be employed in connecting other instruments to the bus bars and machines.

When the corresponding circuits of the line and the incoming machine have been located the main circuits of the incoming machine should be so connected to the switches that the main circuits of the machine will be connected to the main circuits of the line when the switches are closed. There is still a chance that the two phases of the machine may be dissimilarly connected to the line so that the electromotive force of one phase will be in phase with the line while the electromotive force of the other phase will be opposed to that of the line. In order to determine whether or not these connections are correct, two synchronizing devices, one for each phase, must be connected in circuit simultaneously. The connections for each phase are identical with the connections for a single-phase circuit shown in Fig 1. If transformers are used with the synchronizing lamps, each set of lamps should be tested out separately as previously described to insure that the lamps will all be dark when indicating synchronism. If the two phases are relatively correct the two sets of lamps will be bright at the same time and dark at the same time when the machine is being synchronized. If such is not the case it will be necessary to reverse the connections of one of the phases of the machine. If transformers are used with the lamps it may now



FOR SINGLE PHASE OR ONE PHASE OF POLYPHASE CIRCUITS 500 VOLTS AND OVER



FOR SINGLE PHASE OR ONE PHASE OF POLYPHASE CIRCUITS 200-500 VOLTS be necessary to change some connections in the synchronizing circuit in this phase, depending upon the place in the main circuit in which the leads were reversed. The synchronizing lamps should therefore be retested to make sure that both sets of lamps are dark when indicating synchronism. It will now be found that when the machine is synchronized and one phase connected to the line, that the lamps in the synchronizer of the other phase will be dark, indicating that that phase is also in synchronism. Therefore, the machine may be synchronized by a synchronizing device in only one phase after the correctness of the connections has been determined.

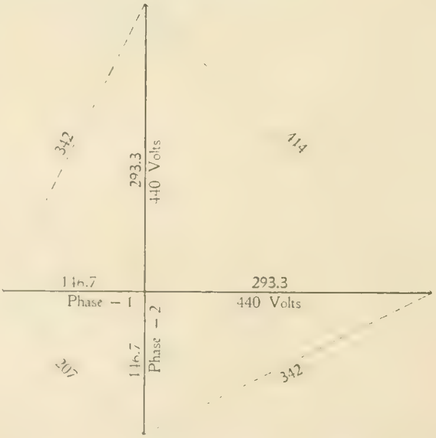
SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

INTERPHASE CONNECTIONS ON TWO-PHASE GENERATORS SECURING LOW VOLTAGES FOR STARTING INDUCTION MOTORS

It was suggested in a recent article on the polyphase induction motor, November JOURNAL, p. 603, that a scale of starting voltages may be obtained from two single-phase transformers by simply connecting the secondaries together at points to one side of the middle point of the winding.

In a few instances this principle has been applied to the windings of the generator armature. The windings are connected together at the one-third point, which gives the various voltages as seen in the accompanying diagram. A fifth collector ring is connected with this common point, which at once provides a two-phase voltage series of 146.7, 293.3 and 440, the latter being the full voltage of the generator. In machines of low voltage, parallel circuits in each phase winding are necessary. In order to make this interphase connection in all the parallel circuits a copper ring is placed on each end of the armature, each ring joining the one-third points of all the parallel wind-



INTERPHASE CONNECTION ON TWO-PHASE ALTERNATORS TO OBTAIN SEVERAL VOLTAGES ings of one phase, and the two rings joined together by a connector passing through the framework of the armature.

BREAKING OF ARMATURE LEADS ON SMALL ARMATURES

The breaking of the wires leading from the armature coils to the commutator on armatures using wire of a very small size is discussed in the supplement to *The Electrical Engineer,* of London, in several replies to a question box conducted by that paper. The following conclusions are given as representing the most probable causes and the best remedies:

The perpetual vibrations to which the short stretches of unsupported wires are subjected in relation to the ability of the wire to mechanically withstand the same is unquestionably the essence of the whole consideration.

The vibrations may be due to (1) vibration of the whole armature due to inaccurate balancing; (2) relative motion between the armature winding and the commutator, owing to the latter being lightly secured to the shaft—e. g., by means of a simple set screw in place of a proper key; (3) electro-magnetic interaction between the currents in the connecting wires and the leakage field in which they rotate; (4) loose or imperfectly fitting of the band wires; (5) imperfect foundation.

These vibrations may be reduced by several different methods; (1) using heavier wire for the connecting leads; (2) doubling the lead back on itself after it has reached its commutator segment, the whole lead then being twisted; (3) reducing the length of the leads, (4) by winding a layer of strong twine over the end connections extending inwards from the commutator necks about one-third the distance from the necks to the armature core plates.

The ability of the leads to withstand these vibrations may be greatly reduced by (1) over heating them while soldering; intense heat tends to crystalize the copper and greatly reduces its strength at that point; (2) by injuring the surface of the wire while removing the insulation.

REPAIRING PITTED COMMUTATORS

Pitting is the term given to the eating away of the insulating strip between two adjacent commutator bars. Anything which will establish an arc between any two adjacent bars for an appreciable length of time, will start a pit. These pits occur sometimes on the face of the commutator, sometimes at the end and not infrequently on any part of the surface where there are sharp corners.

When a pit is discovered, the hole should be cleaned out thoroughly with a sharp steel instrument, taking care that the carbonized mica is cut out entirely, and also that the projecting points on the copper between the bars caused by the arcing, are smoothed off. The hole should then be filled with mica if a large one, or a mixture of plaster of paris and shellac if a small one. If the pit is carefully cleaned, this will prevent any further pitting at that point.

EDITORIAL COMMENT

The Evolution of the Switchboard

In the early day of electric lighting there was no switchboard *per se*. There were switches, and indicating instruments such as ammeters and voltmeters, but of doubtful veracity. Protection was furnished entirely by fuses.

I remember well one of the early direct-current plants. The generator switches were on one side of the dynamo room; the field rheostats and machine voltmeters were on the opposite side; the feeder regulators with feeder voltmeters were on a third side. Off in one corner were the ammeters, and the feeder plug-switches with the fuses were in still another corner. This plant was a fair example of the old way of laying out a station where the steam plant was first provided for, the generators squeezed in, and whatever space remaining was utilized for the necessary switching and regulating appliances. The arrangement was admirably designed to give exercise to the station attendant.

Although the different appliances were scattered all around this station, the engineer who made the plans evidently had a clear notion of what he desired to accomplish. In a general way his idea coincided with modern practice; separate and independent control of the generators, and of the feeders as far as possible, together with protection at every point where a feeder left the station.

The next step was the assemblage of the switchboard apparatus on a single board, usually of wood, which was mounted against a wall of the station, but the crowding of wires in the confined space back of the board naturally led to much trouble and gave little opportunity for inspection or repairing. The board was then placed at a distance from the wall so that a man could easily get behind it. This plan was regarded by many as a wicked waste of space and an invitation to the electrical tinker to engage in dangerous experiments.

The number of fires started by short circuits on wooden panels soon made it apparent that a fireproof material was absolutely essential for the safe mounting of live wires. This brought out the marble panel, having a definite arrangement of instruments and so constructed that the different panels could be grouped to form a switchboard consisting of generator panels, load panels, feeder panels, etc., each distinguished by an arrangement of instruments designed for the special service required.

Mr. Peck, in his article on "Modern Practice in Switchboard Design," beginning in this issue of THE JOURNAL, opens up a subject of vital importance. He points out that a thorough knowledge of this subject is essential to the engineer, whether he is making a specialty of the operation or the construction of plants, or the design of apparatus. Consulting engineers already realize the importance of this part of the plant and every year it receives increased attention from them.

Mr. Peck also draws a striking analogy between the office of a large manufacturing plant and the switchboard of a power plant. It is evident that the total output of the power station is brought to a focus at the switchboard, as the manufacturer's business is focused at the main office. The importance of the switchboard as the central point from which an electrical system is operated and controlled should direct attention to it and make it one of the features to which the greatest care is given in the design of a large plant.

C. I. YOUNG.

A Man's Work The relations of different men to their work are determined from widely different points of view.

One man will work entirely for the money he receives. The work he does is limited by his own estimate of the value of his compensation. The value of this work, both to himself and to his employers, is influenced by every little current of circumstance to which he is subjected.

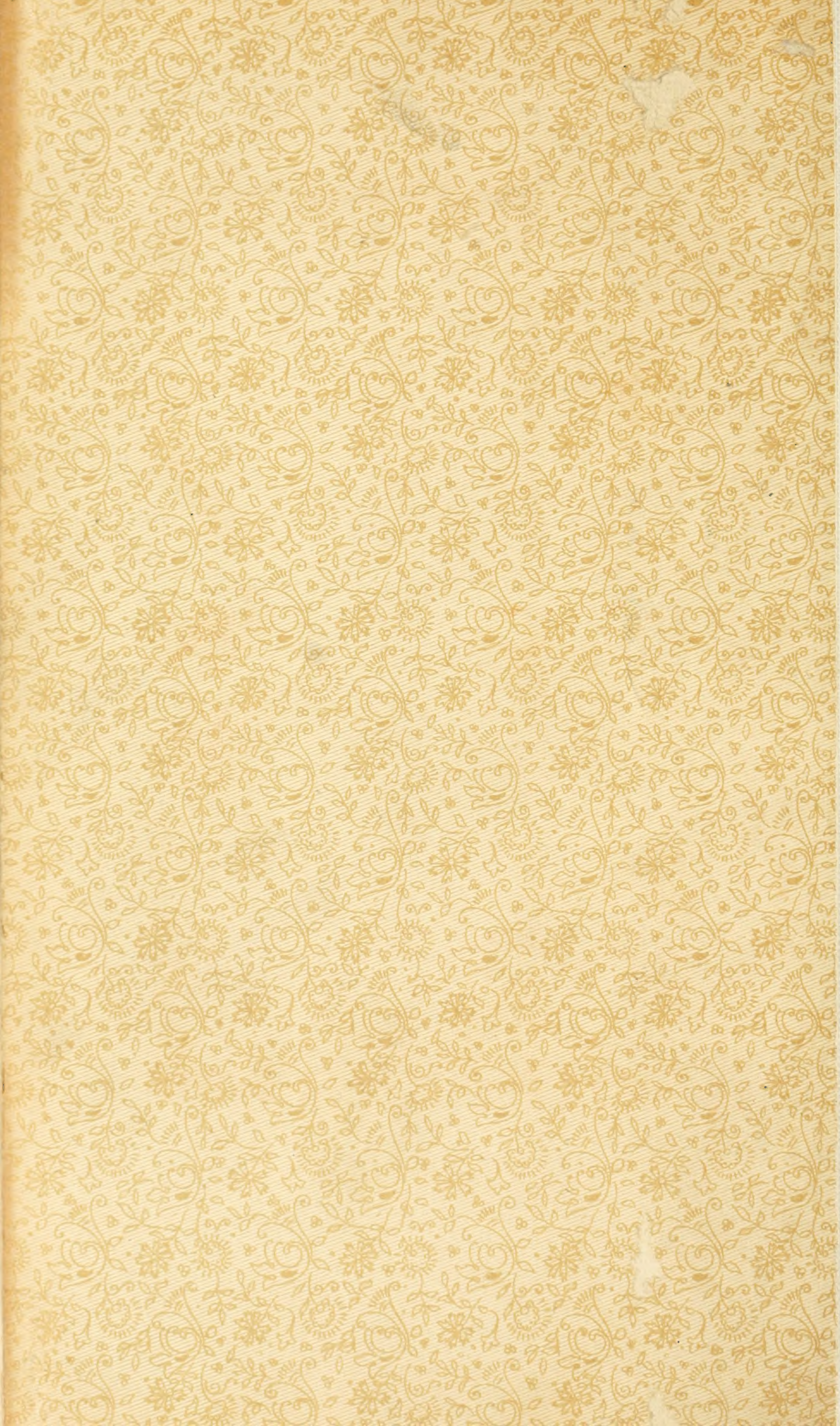
A second man will labor for the good the work does him. His capacity and ability are the only limits to the amount and kind of service he will render. Salary, the personal qualities of the men directly above him, and other things that do not affect the value of his work to himself, are of secondary importance. Doing his work to the best of his ability is a simple matter of loyalty to himself. He is above the influences of these circumstances.

A third man will do his work not only for the benefit of it to himself and for his future advancement, but for the accomplishment of results. He is not essentially different from the second man; he is merely a step farther along in his development. In an organization of men the second man may be of restricted usefulness. Self-centered, he may easily miss his part in the common interests and purpose of the organization. The third man, on the contrary, looks beyond himself to the results of his work. Of necessity, he feels himself a part of the organization; he is as intent upon its achievements, its development and its success, as he is upon his own.

In the rank and file of an industrial company this identification of the individual with the organization interests comes most easily through a feeling of loyalty to the company on the part of its members. Whether a man works only for the money he receives or for his own growth and development depends mainly on the man—on his own way of looking at things. But whether a man works for the best interests of his company, as well as for his own best interests, depends largely on the character of the company. It must be one worthy of loyalty. But assuming that it possesses such a character, how can a company show it and prove it?

Aside from the fundamental requisite of fair business relations between the organization and its members, there is no more certain way of doing this than by making the younger men know the men who direct the policy and work of the organization; the character of the company is merely a composite reflection of the characters of these men.

Considering these things, the work of THE ELECTRIC CLUB in its relation to the Electric Company assumes a deeper significance. The technical value of this work to the members needs no emphasis. We wish to direct attention to the less evident, but more important, result of this work in bringing the different groups of men in the company together, in giving them the opportunity of knowing and appreciating each other: in the section meetings bringing the engineers and apprentices together, and in the lectures bringing the officials, engineers, apprentices and shopmen together. This personal association which the club makes possible is of even greater importance than any amount of instruction or entertainment.



Author ELECTRIC (CLUB) JOURNAL 122453 Technol P

Title VOL I 1904 E

UNIVERSITY OF TORONTO
LIBRARY

Do not
remove
the card
from this
Pocket.

Acme Library Card Pocket
Under Pat. "Ref. Index File."
Made by LIBRARY BUREAU